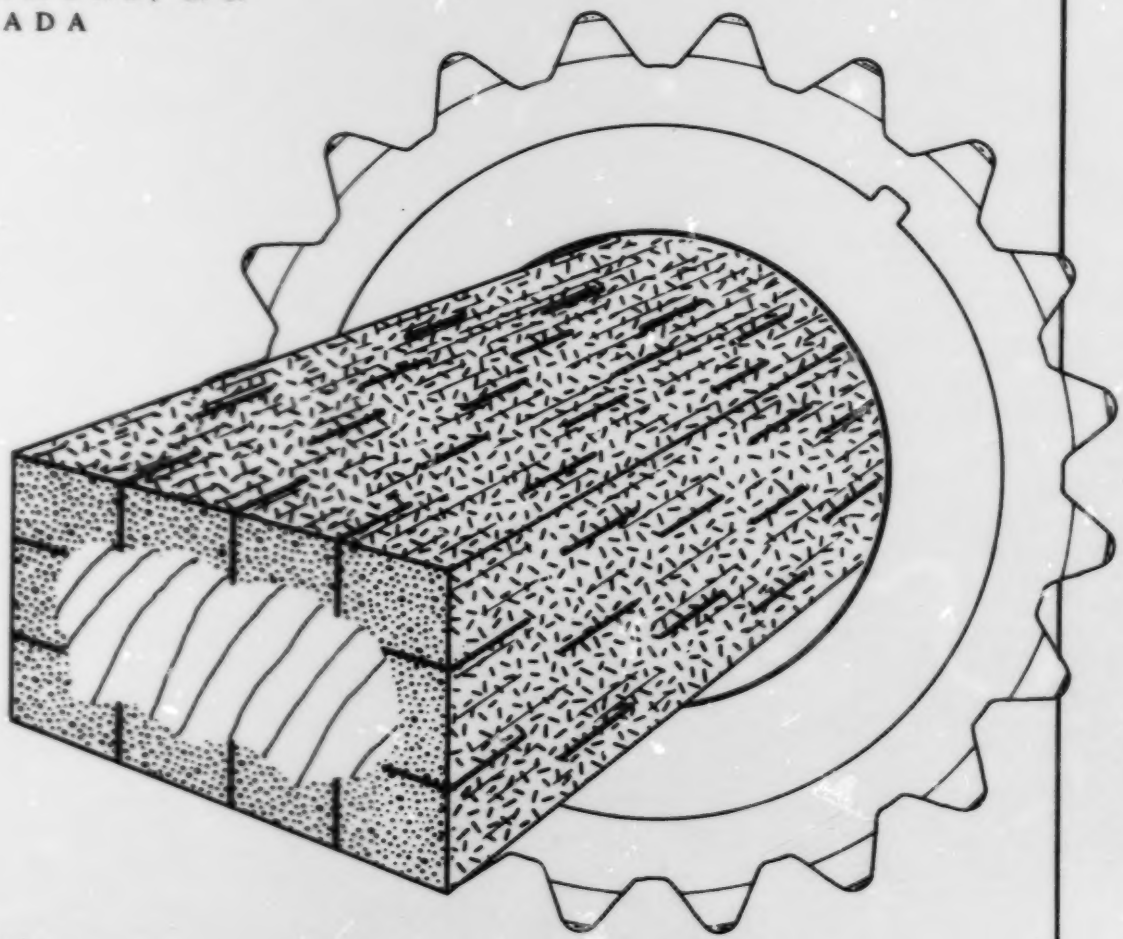
INCISING WORKSHOP

PROCEEDINGS

OCTOBER 2, 1986
RICHMOND, B.C.
CANADA



Forintek Canada Corp.

• SPECIAL PUBLICATION No. SP-28 • APRIL 1987 •

87-05671/

INCISING WORKSHOP -- PROCEEDINGS

VANCOUVER, CANADA
OCTOBER 2, 1986

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April, 1987
SPECIAL PUBLICATION NO. SP-28
ISSN 0824-2119

ACKNOWLEDGMENT

Forintek Canada Corp. wishes to acknowledge the financial support received from the Canadian Forestry Service and the help and collaboration of our staff, without which the workshop could not have taken place.

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INTRODUCTORY REMARKS

Good morning ladies & gentlemen.

Let me extend a special welcome to members of our audience and to several of our speakers who have come from Europe and Japan to participate in Forintek's Incising Workshop. It was about a year ago that John Ruddick began planning the workshop. At that time, we expected about 30 or 40 participants, if we combined our workshop with an industry association meeting. I am pleased to report that our attendance exceeds 80. We have participants from all across Canada, the U.S. as well as Europe.

Clearly, the outstanding response today recognizes the importance of incising in wood preservation. There are two reasons that come to mind. First the refractory nature of our wood resource makes incising a key factor in product quality. In Canada, the heartwood of most of our species is difficult to penetrate with preservatives, hence incising is necessary to assure the long term performance of wood in ground contact. However, even with incising, treated wood products do not consistently meet the preservation standards. Secondly, incising impacts on the marketability of treated wood. As you know, the process of incising damages the surface of the wood, detracting from its appearance and reducing strength. There is an urgent need for equipment that improves preservative penetration, while minimizing wood damage.

During the presentations this morning, we will learn about several new technologies. Some of these have received limited application while others are still at the experimental stage. Perhaps it is time we update our knowledge and examine these technologies in the light of current equipment advances, and market strategies for treated wood.

In the afternoon we will hear about the latest developments in mechanical incising. These are technologies that are being commercialized today and will find application in the short term. Our final presentation will consider incising from a somewhat different perspective. We will examine the effect of incising veneer on plywood processing with the added benefit of producing a treatable panel.

I am confident that you will find our program extremely informative. You will leave with a better understanding of how incising fits into your operation today and an awareness of the opportunities that await you tomorrow.

If any of you are staying over until Friday, I invite you to visit Forintek's laboratories. We have recently installed a fungal cellar for rapidly evaluating preservative performance, which we are eager to show off. If you are interested in a tour of our wood preservation facilities or a discussion of our research program, please see me during the day to make arrangements.

George Rosenberg
Manager
Treated Wood Department

LASER INCISING OF WOOD

by Francois W. Kropf
Swiss Laboratories for Materials Testing and Research (EMPA)
Switzerland

1.0 INTRODUCTION

The necessity to pressure-treat construction lumber and particularly glue laminated beams when exposed to the weather is hardly questioned any more, not even in Europe. Wherever rapid drying of the wood after moistening by rain is not obvious, such members are bound to be attacked by fungi and rot away quite quickly.

In Switzerland, and for that matter in most of Central Europe, the major wood species used for construction lumber is spruce (**Picea abies**). It may be added that in Europe the construction practice has traditionally been the use of large cross sections (standard cross sections go up to 20 by 26 cm). A normal roof construction will easily use beams between 20 by 30 and 25 by 40cm.

So far no pressure treatment process could ensure a sufficient penetration of the preservative into spruce beams of such dimensions — sufficient meaning to a depth greater than the potential checking of the wood during service time. The penetration is usually substantially better in white fir (**Abies alba**) but the results are not very reliable. The heartwood of pine and Douglas-fir behave approximately the same as spruce.

This situation, coupled with the need to find new outlets for a generous supply of home grown wood of not particularly good quality, has led to a renewed interest in the pre-treatment techniques to increase the penetration of the preservative into the wood.

For many years, we have been working on what we call the "weatherproof glulam" and all our investigations of perforation systems have been performed with this goal in mind. We are convinced that quite a potential of new wood applications could be opened, if we could succeed in improving the weather resistance of glulams by a factor of two or three.

Of course this cannot be done with chemical preservation only, but we consider preservative treatment a decisive step, for it is all too well known to us — and I am sure this applies to your countries as well — that maintenance of such structures is only undertaken when the damage is already quite advanced. The greater the preservative penetration into the cross section of any beam, the better the entire member will be protected against fungal attack.

As the mechanical perforation was reaching limits which were unlikely to be overcome independently of the system, we thought that laser perforation could be the answer.

2.0 ADVANTAGES OF LASER PERFORATION

Considering the limitations of the conventional mechanical incising technique, these being mainly:
- limitation of depths to 6 - 8, at best 10 mm
- unsightly holes
- loss of strength
- wear and tear of equipment
- increased glue consumption for glulam manufacturing;

The laser perforation technique has a number of very interesting features, including:
- nearly "invisible" holes (after planing)
- reduced strength losses by the incising process
- improved incision depth
- little wear and tear, since there is no contact between workpiece and tool.

The major detraction of laser perforation is not technical, but up to now its cost.

3.0 HISTORY OF OUR TESTING

The very first tests were carried out during the late seventies and showed the basic feasibility of shooting holes into wood with a laser beam. At that time the laser technology was still developing the pulsed laser beams, which were much more effective for the machining of materials. A patent was even released to a Swiss wood preserver but found no direct follow-up, until we also started to look into this matter in 1981.

Also in 1981, a symposium of the Eastern European countries took place in Bratislava, where the various uses of lasers in wood machining were extensively discussed. It was very difficult to obtain copies of the papers presented there, with respect to their German translations, as this conference was definitely not intended to provide information to the "West". Scanning through these very elaborate papers showed mainly that much of the basic work had already been done, even if it was not readily available to us, and it confirmed that we were on the right track. Rather than repeating this basic work, we decided to concentrate our investigation on the practical aspects of the laser perforation of wood.

4.0 FIRST TESTING SERIES

We established contact with a small engineering company called Laser Work AG in Pfungen near Zurich, who at the time was mainly machining workpieces to specifications and was experimenting with the pulsing

technology. The company could not afford to do our testing for free, so we had to mobilize research money to buy machine-time from them, but at least they were small enough to be co-operative and to listen to our wishes and ideas. Today, they are one of the leading laser-application companies in Europe, but they still listen to us since we have been in on it right from the start.

It took almost a year to prepare this first testing series. It had to be carefully planned to efficiently carry out the actual incising since we could not buy unlimited time from the company.

4.1 MATERIALS AND METHODS

The parameters of interest for that first testing series were:

1. **laser beam**
   - duration of pulse
   - angle of impact into wood
2. **wood samples**
   - 2 species - spruce and white fir
   - 3 wood densities - fine growth rings
     - medium growth rings
     - large growth rings
   - 3 wood moisture contents - 7% (ca 35% rel. H.)
     - 13% (ca 65% rel. H.)
     - 25% (ca 95% rel. H.)
3. **additional parameters**
   - board moving continuously (approx. 7 cm/sec)
   - shooting through glue-lines
4. **pressure treatment**
   - waterborne salts, mainly chromated-copper-fluoride (CCF)
   - oilborne organic preservatives with water repellent properties, consisting of a solution of 15% alkyd-resin and 0.2% paraffin — a formulation used successfully in glulam manufacturing

Each parameter had three replicates from the same piece of wood and a non-perforated control, thus providing 20 samples for each species and each preservative treatment.

The size of the samples was: length = 350 mm
width = 80 mm
height = 50 mm

Eight laser holes were shot into each block, 40 mm apart across the grain and 80 mm apart along the grain. These distances were deliberately chosen to be greater than the expected penetration of the preservative, to allow a measuring of the actual penetrations.

For white fir the chosen spacing of the holes was too small; the samples were practically impregnated throughout and no distinct penetration distances could be measured.

4.2 RESULTS

4.2.1 Laser Beam

- Pulse duration and depth of penetration are related in a non-linear (i.e., logarithmic) curve (Figure 1).
- The depth of penetration is not only influenced by the density of the wood but seems to depend also on some anatomical characteristics of the species. This would explain why a dense beech wood showed a practically identical penetration curve than a much lighter spruce.
- The angle of impact into the wood surface has **no significant effect** on penetration depth; the wood surface or latewood rings do not deflect the laser beam. As a matter of fact, shooting into the wood at an angle seems to have even an advantage, as the exhausting combustion gases can escape more easily, reducing the possibility of contaminating the laser lens, or interfering with the laser beam.

In order to understand better what is happening during the shooting of a laser hole, special blocks were prepared onto which a quartz glass was glued and screwed on. These blocks were then positioned in a way to make sure that the laser beam was shooting exactly into the plane of the interface. The actual shooting was then filmed with a high speed camera taking 3,000 pictures per second. The results will be shown in slow motion at the end of the presentation.

4.2.2 Wood Species

The spruce samples showed large variations of the longitudinal penetration and much overlapping of the penetration areas, but in the average of the 160 holes the curve shown in Figure 2 could be developed. The areas to the right and left show the range of the standard deviations. The average longitudinal penetration at a depth of 10 to 20 mm from the surface was roughly 35 mm and in depth less than 5 mm below the bottom of the hole, at least for the depth of the hole tested of 35 mm, which was the maximum of interest for us.

Across the grain the average penetration was limited to 2 mm on either side of the hole. These results confirm measurements performed by others after mechanical incising (Sell and Gjovik, 1985). In other words, for preservative penetration a laser hole fulfulls its purpose at least as well as an opening produced by mechanical means.

4.2.3 Variation of Wood Density

Pulses of the same energy level penetrate further in wood of lesser density. This, however, is no surprise, as less material has to be burned up in entering the wood

and thus the energy available does carry further. Up to now, we have not investigated this parameter further, as within the density variation of the woods we plan to pretreat with this technology, it is covered up by the variations of the wood material.

4.2.4 Wood Moisture Content

The trend indicates that higher wood moisture content reduces penetration. This can also be explained with the consumption of the available energy; part of it serves to evaporate water and cannot work on the drilling depth.

4.2.5 Moving Work Piece

A process speed of 7 cm/sec (= approximately 4 m/min) had been estimated as a minimum for any kind of practical application. Until now the board was in movement during the laser incising and obviously the round holes became short slits. But even for a maximum shooting time of 50 millisec, they were still small enough for our purposes.

Interestingly enough the depth of penetration for a given energy level was not much less than that achieved in a stationary board. This may be explained by the fact, that now the combustion gases can exhaust better and interfere less with the laser beam, compared with the stationary board when both the laser beam and the exiting smoke must move in opposite directions in the same cylindrical incision.

This finding is of great practical importance, since it allows the design of a continuous process, which is much more efficient than an operation where the board movement is halted during the actual laser incising process.

4.2.6 Shooting Through Glue-Lines

For all thre types of glue tested, resorcinol, isocyanate and urea, we found, as anticipated, that the glue-line was not a barrier to the laser beam.

4.2.7 Pressure Treatment

A chemical reagent (α- naphthol, 0.2 - 0.5%) had been mixed into the oilborne preservative solution, to allow visualization of the penetration by reaction with a solution of Fast Blue B-salt (0.5%). Thus, the penetration could be determined for both preservative solutions, waterborne salts, and oilborne preservatives. Both treatments had been run at a standard commercial schedule. The penetration of the oilborne product was somewhat less than for the salt solution, but comparable results can be achieved by adjusting the treatment schedules.

5.0 SECOND TESTING SERIES

5.1 PERFORATION PATTERN

During earlier tests with mechanical incising the Western European Insitute for Wood Preservation (WEI) had improved the conventional incising pattern by arranging the incisions on slanted lines across the board (Figure 3). The first series of laser experiments used that pattern without modification. The processing of the boards demonstrated, however, that this pattern was quite impractical for laser treatment, as it could not be fitted into a continuous process with a single laser source doing the shooting. Thus a new pattern was developed, which could be shot onto the wood more efficiently.

- The basic idea was to have the nozzle of a pulsed laser beam travel back and forth between two endpoints on either edge of the workpiece. The workpiece itself was to be moved at a continuous but adjustable speed, thus allowing a match of the number of holes per unit area to the wood species and the required level of protection (see also Sell and Gjovik, 1985).
- The resulting perforations were arranged on a zig-zag pattern. By only shooting for half of the way across the board, the perforated zones were quite well distributed and one still obtained theoretically a full coverage of the entire board surface (Figure 4).

A test series was run on boards processed with this pattern to determine if the loss of strength was in the same range or less as with other incising methods. This proved to be the case: depending on the steepness of the zig-zag, with respect to the speed of the board, the MOE of the individual board was reduced by 7 - 10% — a value which we consider negligible when working with the design values of MOE.

Regarding MOR and with the glulam manufacturing in mind, we performed bending tests on boards of 35 mm thickness after a two-sided perforation to a depth of about 15 mm from either side. For these thin individual boards the reduction of MOR was between 15 and 20%, but will of course be much less for larger cross sections. The remaining strength was still well beyond design values of the codes.

We do not yet know how this reduction of strength of the single lamella will affect the strength of the finished glulam, so for the time being we advise increasing the height of the cross section by 5 - 10% to account for this possible reduction of MOR and be on the safe side. We are, however quite confident, that a rigorous investigation of this aspect will show that eventually this reduc-

tion of MOR for the single board will be close to negligible for the standard glulam design.

5.2 THE SO-CALLED "DOWELLING EFFECT"

At one time it had been thought that the holes in the gluing planes would improve the anchoring of the glue and thus lead to an increased shear strength of the glue-lines. It has been demonstrated conclusively, that for the large incisions of the regular mechancial incising, this is not the case with the glues customarily in use today. The result for laser processed boards is based on a smaller number of samples, but showed that as long as the holes are small, the strength of the glue-line remains unchanged, and only when the holes get bigger (50 millisec) a slight reduction of the shear strength can be observed.

Unfortunately, no dowelling effect has been observed, at least not with conventional glues.

5.3 RECOMMENDED LASER BEAM DURATION

As was shown by the early experiments, the depth of the holes can easily be increased with the laser technique, but demands a disproportionate amount of time, with respect to energy. Therefore, we feel that for wood processing and particularly glulam manufacturing, it is more efficient and will provide better preservative treatment when either side of the board is being perforated to a depth of 10 to 15 mm. This will also use less energy and bring about less of a reduction of MOR.

Today already higher energy lasers are available at reasonable cost, and a "split beam" system can allow incising of both faces of a board at the same time. Such a pilot machine is on the drawing boards of the Laser Work Company previously mentioned, and we count on running further tests sometime next year. It will be equiped with a 1.3 kW-Laser — an economical, not a technical choice — and will process double-sided 15 to 20 cm wide boards at a rate of about 10 m/min. This is an improvement by a factor of 4 from the minimum we had set in the beginning of our trials, and we are being told that we have not yet reached any technical limits.

6.0 CONCLUSIONS

In regard to the single hole, the laser perforation has the following advantages:

- The actual shooting, i.e., burning of a single hole is, at least for the small penetration depth up to 20 mm, extremely fast.
- At the time of our first tests a hole of 15 mm was achieved in less than 20 millisec. With today's laser the same hole can be obtained in 8 - 10 millisec.
- The laser-shooting of a hole creates an actual void space in the wood without vitrifying or crushing of the fibres, which would otherwise plug up the neighboring areas. Therefore, this hole will remain and cannot close up again due to relaxation of the tissue or wood swelling during pressure treatment.
- The diameter of the holes is a function of the depth, but stays small. To a depth of 15 mm, the holes were less than 0.5 mm in diameter. For a shot to a depth of 35 mm it was at the most 1.5 mm, and this, deep in the wood, as opposed to any known mechanical system which makes the biggest marks at the surface where they degrade and weaken the wood member the most.
- The correctly controlled process destroys only little wood substance. A rough approximation would give about 18 cm^3/m^2 with a pattern of 3,000 holes/m^2. The same pattern would damage around 500 cm^3 with mechanical incising to a depth of 10 mm.
- The surface shows only small burning marks which are invisible after light planing or sanding.

To sum up, we are convinced that the laser perforation of refractory wood species such as spruce will open new possibilities to put our lower quality wood resources to a good use. In this sense we do not see laser perforation in competition with mechanical incising, but as an additional technique to be used where deeper penetration or high quality appearance of the wood surfaces is required. It will then allow new applications of wood which so far were not possible.

From the point of view of wood technology, we feel that most of the essential technical knowledge has been developed. Further optimization must be done by the laser application people and is underway. We see no major difficulties from our perspective, and think that the economic problems which have so far held up the development can be resolved with the new more powerful lasers. One should not brag about a fish one has caught before it is on land, but we are quite confident that by next year we will be able to get a substantial step ahead and reach the pilot state. The necessity to increase the wood harvest in our largely over-mature European forests has brightened the chances for projects leading to innovative uses of this resource — and we are ready to take advantage of it.

7.0 REFERENCES

Sell, J. and L.R. Gjovik. 1985. Pressure treatment of microincised spruce with ammoniacal copper arsenate (ACA) and chromated copper-arsenate (CCA). Holz als Roh- und Werkstoff. 43:482.

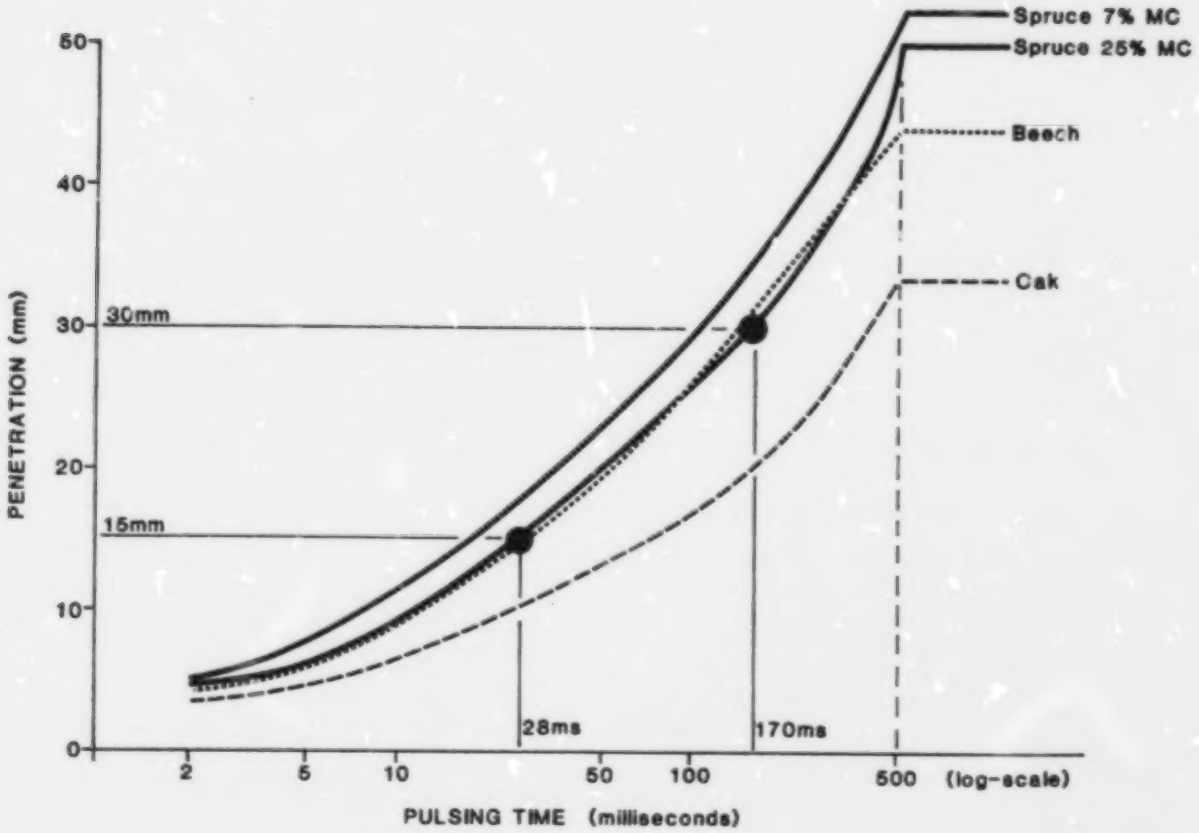

Figure 1 Penetration vs pulsing time (300 watt laser).

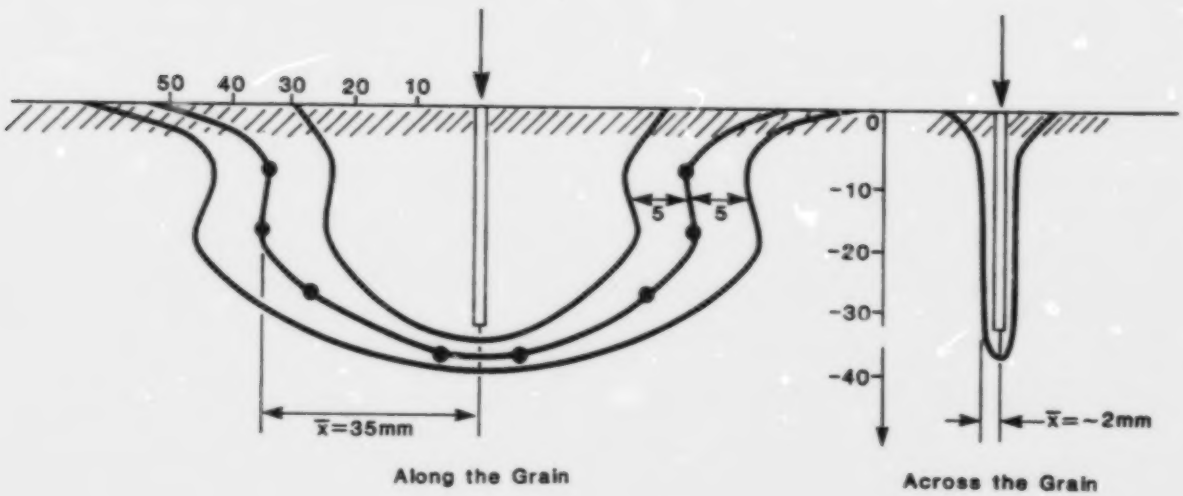

Figure 2 Preservative penetration in spruce.

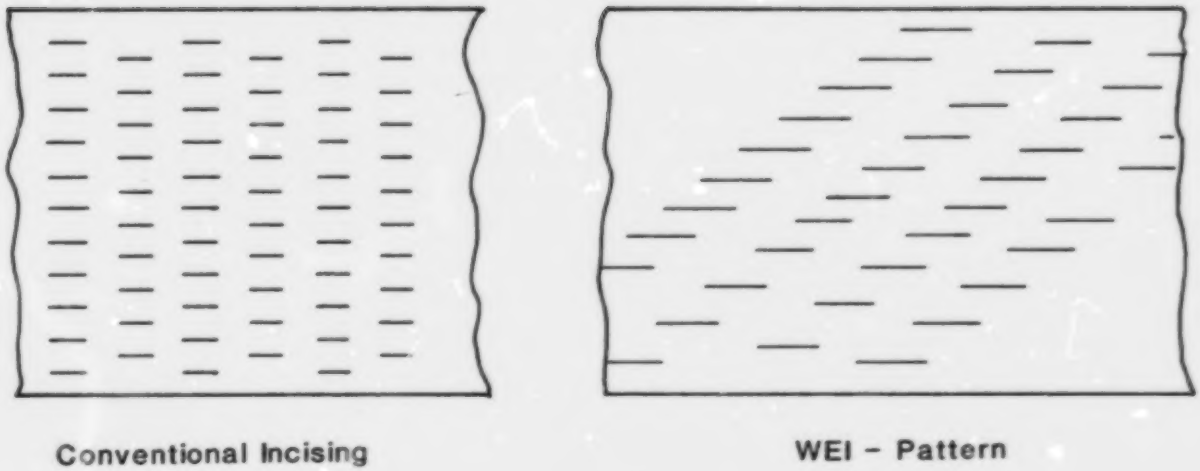

Figure 3 Incising patterns used in early studies.

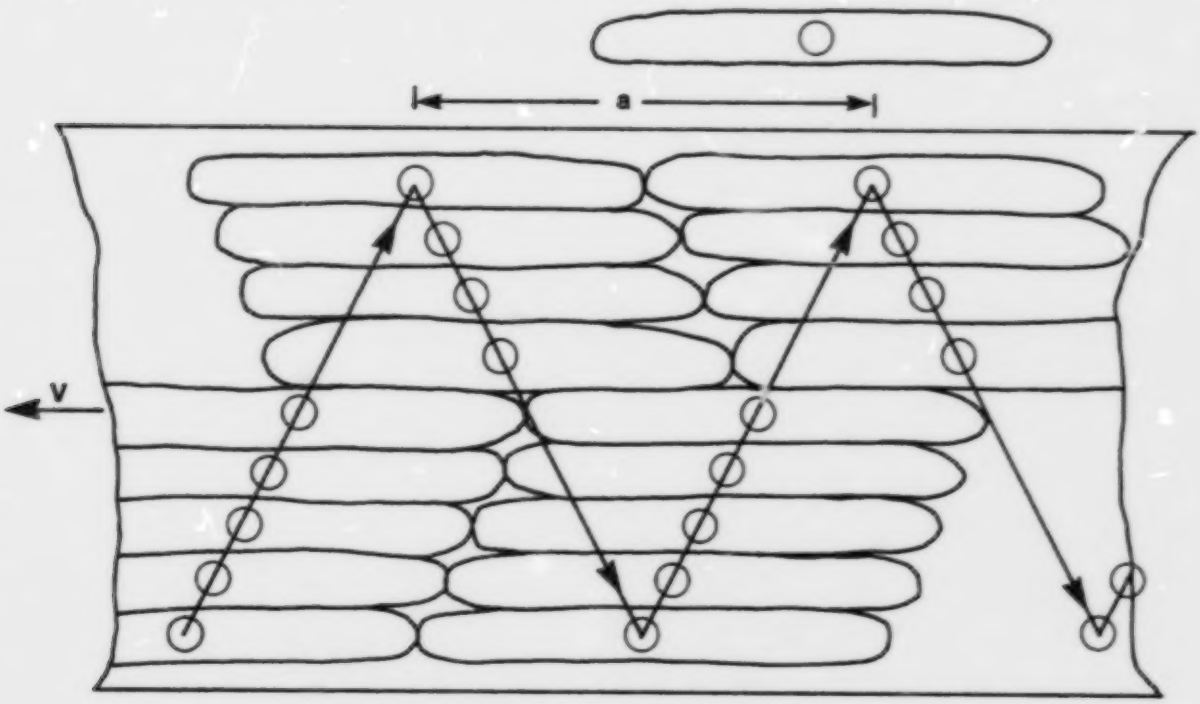

Figure 4 The EMPA - Lap II Pattern.

LASER INCISING OF CANADIAN SAWNWOOD TO IMPROVE TREATABILITY

by J.N.R. Ruddick
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SUMMARY

Air-dried black spruce and kiln-dried Douglas-fir boards were incised using a carbon dioxide laser. Following preliminary experiments, it was established that a laser of 125 watts with a beam duration of 0.03 seconds produced incisions with a depth of 10 mm. The incision diameter at the surface was ca 0.7 mm. Increasing the energy of the laser increased the surface browning, due to the heat developed during the vaporization of the wood by the laser.

Chromated-copper-arsenate (CCA) pressure treatment of black spruce boards incised with 13,888 incisions per square metre did not produce an integral shell of treated wood. Reducing the longitudinal separation of incisions from 72 mm to 36 mm or 24 mm improved the treatment sufficiently to allow the samples to exceed the requirements of the Canadian wood preservation standard. The penetrations and retentions in Douglas-fir boards incised with dense patterns having longitudinal spacings of incisions of 24 mm and 18 mm exceeded those required by the Canadian standard.

Increasing the laser energy and the beam duration resulted in complete penetration of the board. An energy-time combination of 200 watts.second was found to provide the 42 mm penetration necessary to penetrate the board.

1.0 INTRODUCTION

Sawnwood produced from Canadian softwoods has a high heartwood content. Hence, apart from a few notable exceptions such as coastal western hemlock and the sapwood species ponderosa pine and red pine, it is difficult to penetrate uniformly with preservative. For this reason, the Canadian wood preservation standard (CSA 080, 1985) requires lumber to be incised to ensure that adequate treatment is achieved. In the conventional incising process, wood passes between rollers containing teeth. These produce slits in the wood, parallel with the grain. The principal disadvantages of this technique are: (a) surface degrade; (b) loss in strength; (c) the down time required to replace broken teeth; and (d) inability to produce patterns which ensure treatment of refractory wood species such as spruce.

During the past decade interest has grown in the adoption of laser technology in the wood products industry. Although this has principally focussed on the cutting of wood (Barnekov, **et al**, 1986; Peters and Banas, 1977; McMillan and Harry, 1971; Parameswaren, 1982; Gruner, **et al**, 1983a and 1983b; Arai, **et al**, 1976 and 1977; Hartmann and Kurian, 1980; Kleskenova and Orech, 1981) research on the use of lasers to incise wood has also been reported (Walchli, 1982; Kropf and Sell, 1983; Simpson, 1987). If laser incising could be commercialized successfully, the problems associated with conventional incising could be overcome. This study was therefore initiated to determine the potential of laser incising to improve the treatability of two refractory wood species, black spruce and Douglas-fir.

2.0 MATERIALS AND METHODS

2.1 INCISING OF SAMPLES

Air-dried samples of black spruce (38 x 95 x ca 600 mm) and kiln-dried samples of Douglas-fir (40 x 85 x ca 600 mm) were used in the study. The moisture content of the spruce ranged from 18 percent to 35 percent, while that of the Douglas-fir was ca 12 percent. The incising of the boards was carried out using a carbon dioxide laser (Everlase 525-1) at the National Research Council laboratories in Ottawa. The laser can be operated in a continuous mode or pulsed between 1 and 2,500 Hz with the pulse length being variable from 100μsec to 11 seconds. The peak puise power for the Everlase 525-1 is greater than 3.5 kwatts, although the maximum average power output is 600 watts. The efficiency of the laser is ca 15 percent. The focussing lens was housed with a unit allowing a jet of compressed air at 140 kPa to deflect smoke and wood particles away from the gallium arsenide lens. Initially a lens with a 127 mm focussing distance was employed, but this was later replaced by a similar lens with a 63 mm focussing distance, since this produced a smaller diameter incision.

Preliminary measurements on white spruce lumber had shown that use of a continuous 125 watt carbon dioxide laser with a wavelength of 10.6 microns and 0.03 seconds duration, produced small circular incisions to a depth of 10 mm. The array of the incisions was produced by moving the sample using a computer controlled 'x - y' table. When the table was operated at 5000 mm/min. the small holes became slightly distorted resembling very small slits. Also the pulse duration had to be increased to 0.07 seconds to obtain a 10 mm deep incision. Therefore for most of the experiments, a table speed of 2500 mm/min. was used.

For the first experiment the incising pattern employed was that reported earlier (Ruddick, 1986). The incisions were separated longitudinally by 72 mm. The columns of incisions were spaced laterally 1 mm, although adja-

cent incisions were separated laterally by 9 mm. Subsequent tests also used the efficiency of more condensed patterns in which the longitudinal spacing was reduced to 36 mm or 24 mm. A sample replication of ten boards was used for each experiment.

For the laser incised black spruce, sections of each board were incised with the incising patterns having 36 mm and 24 mm longitudinal separation, to allow direct comparison of the two patterns. Equivalent boards from the same source and batch were incised with the less dense pattern having a 72 mm longitudinal separation. Unincised sections in each board were used as reference material.

The Douglas-fir boards were incised with two patterns, having 24 mm and 18 mm longitudinal separation of incisions. An additional Douglas-fir board was incised using a higher energy beam and/or a longer beam duration, to determine the conditions required to penetrate completely 42 mm thick material.

2.2 PRESSURE TREATMENT OF SAMPLES

All test samples were pressure treated with chromated-copper-arsenate (CCA) solution, using a full cell process. The solution strengths were 2.2 percent for the black spruce and 2.7 percent for the Douglas-fir. For the black spruce the process involved an initial vacuum of 100 kPa applied for 30 minutes, followed by a pressure of 850 kPa for 30 minutes which was increased to 1000 kPa and held for seven hours. A similar schedule was used for the Douglas-fir, although the pressure duration was only six hours. The boards were allowed to air dry prior to sampling for preservative penetration and retention.

2.3 ANALYSIS OF SAMPLES

After drying the boards were cross cut and the freshly sawn surface sprayed with chrome azurol S to show the overall preservative penetration. Random sampling, using thin slices cut from each board, was used to provide a preservative penetration value for each test sample. This penetration data allowed the effectiveness of the incising process to be monitored. The boards were individually sampled and the sawdust compressed to form a disc for preservative assay using energy dispersive x-ray spectrometry. The analysis is routinely done using a computerized program to correct the x-ray counts for matrix and interelement interference effects.

3.0 RESULTS AND DISCUSSION

3.1 BLACK SPRUCE

The improvement in the treatment of the black spruce with an increasing incision density is clearly evident in Table 1. When the incision density was 13,888 incisions/m^2, (i.e., a longitudinal separation of 72 mm), the samples often showed areas of untreated wood surrounded by other regions which were well treated (Figure 1). Planing the surface of the sample to remove the outer ca 4 mm, showed that the longitudinal penetration of the CCA was generally limited to ca 10 - 15 mm from each incision. However occasionally the penetration was limited to only 8 mm. The straightness of the grain appeared to influence the integrity of the treated portion. Where the wood between adjacent incisions contained an earlywood-latewood boundary, the earlywood was often treated up to the boundary, but not beyond it. In some cases the earlywood was well penetrated but the latewood remained unpenetrated. In other regions where the incision was located in the latewood portion of an annual ring, the preservative did not penetrate fully the adjacent earlywood in the same annual ring. End grain penetration from the unsealed ends of the board averaged 15 mm.

From these observations it may be concluded that the treatment of the samples incised with the 72 mm and 36 mm longitudinal separation of incisions will not produce an integral outer shell of CCA treated wood. Instead, regions of poorly penetrated wood will occur between the incisions. This was confirmed (Table 1) when the number of penetration samples which achieved (or exceeded) the 10 mm minimum penetration requirement in the CSA wood preservation standard for lumber was calculated. With the 72 mm spacing only 67 percent of the measurements met this requirement. Decreasing the spacing to 36 mm significantly improved the number to 80 percent, while the use of the 24 mm spacing allowed a 95 percent conformance to be achieved. The results for the 36 mm and 24 mm penetration measurements are in compliance with the requirements of the Canadian standard (CSA 080.2, 1985).

The average penetration values also increase with decreasing spacing (Table 1). The 9.9 mm value for the longest spacing reflects the larger number of penetration measurements failing to achieve the desired 10 mm penetration. The 12.5 mm achieved for the most densely incised boards is well above the minimum CSA value.

The average CCA retention values of 8.9 - 11.5 kg/m^3 all exceed that required by lumber in ground contact. However only those for the boards incised with the 36 mm and 24 mm patterns exceeded the 9.6 kg/m^3 retention required by preserved wood foundation lumber.

3.2 DOUGLAS-FIR

The laser incised Douglas-fir boards incised with either the 24 mm or 18 mm pattern were well treated. The average penetrations of 15 mm (Table 2) are well in excess of the Canadian standard requirements, while the

retentions easily exceeded the requirements of preserved wood foundation material.

While the results appear to be very encouraging, since the successful CCA-treatment of Douglas-fir is known to be difficult to achieve, it was noted that penetration of the latewood portions of each annual ring was rarely achieved. Thus when cross-sections of each board were viewed, regions of poorly penetrated wood could be observed. Where an incision was located in the latewood board close to the cross cut surface, the width of the treated portion corresponded to that of the incision with very little lateral penetration. Further studies are needed to determine whether this phenomenon was related to the laser incising or the refractory nature of the wood.

3.3 INCISING THROUGH THE CROSS-SECTION

The results of incising the Douglas-fir sample with a range of laser beam energies and durations is shown in Table 3. Using the 125 watt laser beam with a prolonged duration of 0.5 seconds in place of the usual 0.03 seconds, increased the incision depth from ca 10 mm to 32 mm. It also, however, increased the browning at the wood surface. Even with a beam duration of one second, the incision did not completely penetrate the board. Instead increased cavitation occurred. The incision diameter also increased uniformly from 0.7 mm at the surface to 1.5 mm at a point 15 mm from the surface. Thereafter the incision diameter decreased. Increasing the laser beam energy to 250 watts increased the incision depth, and with a duration of 0.8 seconds allowed the incision to completely penetrate the board. A further increase of the beam energy to 500 watts, allowed the beam duration to be reduced to 0.5 seconds, while still allowing complete penetration. With the higher energies the incision diameter at the surface of the board approached 1.0 mm.

The various laser beam operating conditions and resultant incision depths were combined to provide a plot of the energy required to create the incision (watts.second) versus the incision depth (Figure 2). A value of 200 watts.second was shown to be required to completely penetrate the board, while approximately 3 - 4 watts.second produced 10 mm deep incisions.

Under the conditions of the study, the maximum throughput of lumber, assuming that all the faces could be incised using a beam splitting arrangement, would be ca 5 m/min. This would be improved through the use of a higher energy beam, but an upper limit of 10 m/min. seems to be realistic, if small holes are desired. If fine slits are deemed acceptable the throughput could be increased markedly, perhaps to 20 m/min.

4.0 CONCLUSIONS

- Improved preservative treatment of black spruce and Douglas-fir lumber by laser incising is feasible.
- A carbon dioxide laser with 125 watts and a beam duration of 0.03 seconds will produce incisions of depth 10 mm.
- An incision density of at least ca 28,000 per m^2 will be required to consistently provide treatment of black spruce to the penetration and retention requirements specified in the Canadian wood preservation standard. This corresponds to a maximum longitudinal separation between the incisions of 36 mm, although a spacing of 24 mm provided a greater measure of compliance.
- An incision density of 42,000 per m^2 provided treatment of Douglas-fir to the standard requirements. Only earlywood penetration was achieved in the heartwood.
- Increasing the laser energy to 250 or 500 watts improved the incision depth and an energy time combination of 200 watts.second was required to completely penetrate the board.

5.0 RECOMMENDATIONS

Further investigation is required to develop the laser incising process and overcome the relatively slow throughput calculated from the results of this study.

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ACKNOWLEDGEMENTS

The author is pleased to acknowledge the assistance provided by Dr. G. McGregor and the staff of the National Research Council Canada, Ottawa, during the laser incising of the wood. The technical support provided by N.A. Ross, D. Minchin and J.K. Ingram is gratefully acknowledged.

Table 1

Preservative Penetration and Retention in Laser Incised Black Spruce

Incising Pattern	Penetration mm		%	Retention* kg/m³	
72 mm separation	9.9	(4.5)	67	8.9	(3.2)
36 mm separation	10.6	(4.4)	80	10.1	(2.0)
24 mm separation	12.5	(1.1)	95	11.5	(1.5)
Control	1.45	(0.7)	--	--	

( )Standard Deviation
* CCA-type c

Table 2

Preservative Penetration and Retention in Laser Incised Douglas-Fir

Preservative: CCA

	Longitudinal Separation	
	24 mm Pattern I	18 mm Pattern II
Penetration - mm	15.0 (1.9)	15.2 (1.3)
Retention - kg/m³	19.5 (3.4)	18.5 (3.8)

( ) Standard Deviation

Table 3

Incision Depth Produced Varying Laser Energy and Duration

Laser Energy (watts)	Beam Duration (seconds)	Incision Depth (mm)
125	0.03	10
125	0.5	32
125	0.6	33
125	0.7	33.5
125	0.8	35
125	1.0	37
250	0.5	37
250	0.7	40
250	0.8	>42
500	0.5	>42
500	0.8	>42

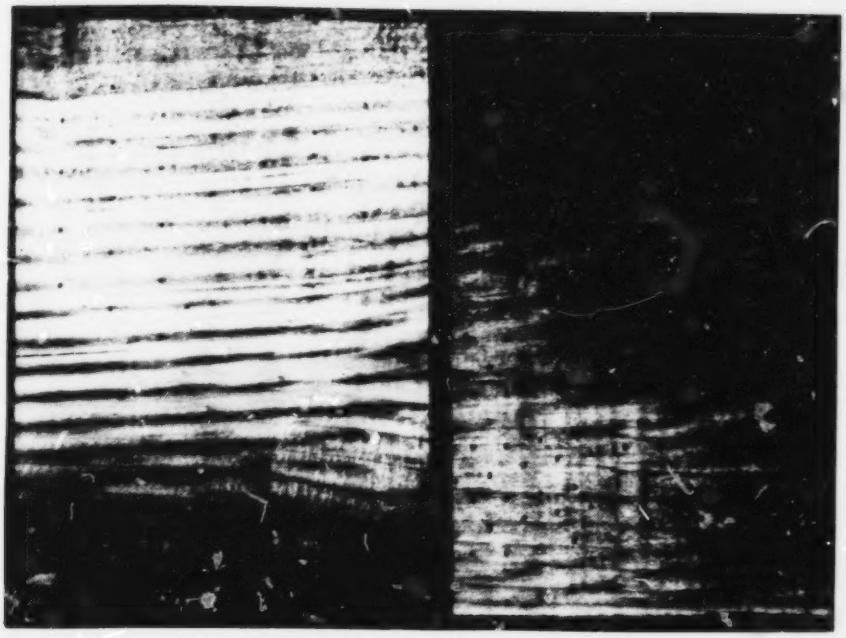

Figure 1 Comparison of laser incised black spruce pressure treated with CCA. The left sample was incised with a longitudinal spacing of 72 mm, while the right sample spacing was 24 mm. The surface of the section was planed to show the preservative penetration.

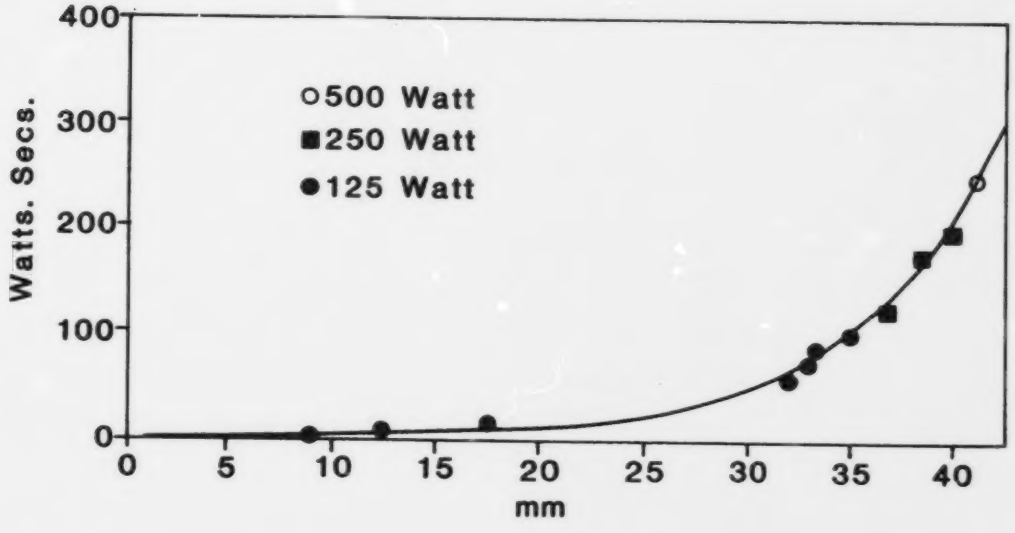

Figure 2 Graph of laser energy times beam duration, and incision depth.

PERFORMANCE OF HIGH PRESSURE JET TREATED 2 X 4 STAKES

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* Paper presented by Dr. R. Jewell

1.0 INTRODUCTION

Bryan 1963, reported the use of high velocity jets as a means of machining wood and in 1967, was issued a U.S. Patent entitled "Method of Impregnation of Porous Materials, Apparatus Thereof and Product Thereof." In the time frame 1967-1970, potential commercial application of this technology was a research program at Weyerhaeuser. It included treatment of plywood and lumber with fire-retardants and biocides. Jet treatment of plywood using fire-retardants produced panels having a Class I noncombustible rating when tested according to ASTM E-84-60 (Nearn and Megraw, 1972).

Conventional treating processes used to impregnate wood with preservatives to meet AWPA retention and penetration standards generally involve vacuum/ pressure processes or thermal dip processes. Incising is required for many species to meet penetration requirements, but this results in an unsightly product. High pressure jet treatment differs from conventional processes in that it is an in-line process as opposed to a batch process, and incising is done by the high velocity liquid jet as it enters the wood. Several potential advantages are offered by this new process: significantly less visible surface damage compared to conventional incising, the ability to treat only a portion of a wood piece, the ability to treat green lumber more effectively and suitability for a compact treating unit for use at the point of sale for treating on demand. The work being reported here summarizes the results of thirteen year exposure testing of 2 x 4 stakes jet impregnated using water and oilborne biocides, thus providing information on whether it is possible to impart decay resistance using high-pressure jets to inject the preservative in a predetermined hole spacing pattern. It is a unique data set and should provide a basis for the application of jets as an alternate means of incising and for use in a number of special or in-place applications.

2.0 MATERIALS AND METHODS

Douglas-fir, western hemlock and ponderosa pine 2 x 4's (5 x 10 cm) were cut into 50 in. (1.3 m) lengths and conditioned at 50 percent relative humidity prior to treatment. The samples were treated one side at a time in a treating apparatus capable of automatically positioning the pieces and firing the high velocity jets of preservative solution at pressures up to 60,000 psi (416 MPa). Figure 1 shows the typical jet pattern on a treated 2 x 4. The general configuration of a single entrance hole and surrounding island of treated wood is shown in Figure 2. Two different techniques were used to reduce visible surface damage. One technique used was to fire the jet through a metal disc clamped to the surface of the wood. The other technique was to submerge the 2 x 4 in treating solution and fire the jet through the solution.

Ammoniacal copper arsenate (ACA) was obtained as a 20 percent concentrate (oxide basis) and adjusted to the desired concentration by water addition. Pentachlorophenol was obtained both as flake and as a 40 percent concentrate and diluted as needed with diesel oil or methylene chloride.

After treatment, the samples were weighed to determine preservative retentions. The ACA treated samples were dead stacked and wrapped in polyethylene for ten days. The pentachlorophenol treated specimens were open stacked using stickers. The ACA treated samples were handled similarly following the dead stacking period.

A stake test was selected near Kalama, WA. Soil samples averaged 5.6 in pH (ASTM D1758-62) and 24 percent in water holding capacity (ASTM D1413). The presence of termites was confirmed. The treated 2 x 4 samples were cut in half and placed in the ground with the cut ends up. Matched untreated 2 x 4 samples were included with the treated stakes.

After removal from the test site, the stakes were rated for decay according to AWPA Standard M7. In addition, the ACA treated stakes were assayed for retention. Three borings were taken from each stake above the groundline and between rows of jet holes and analyzed by ICP spectrometry. Preservative penetration was measured for each stake by cutting in half, applying chrome azurol S to the cut end, and averaging the penetration from both edges. A group of ten Douglas-fir ACA stakes were more intensively analyzed, taking additional borings directly on the jet holes, and another series of above ground borings between rows of jet holes to study the retention at depth increments of 0.2 in.

3.0 RESULTS AND DISCUSSION

In examining the treatment data, several trends are apparent. Increasing the nozzle pressure and preservative solution concentration increases retention. Increased retentions also result from jet treating pieces submerged in treating solution in comparison to the jet treatment using a disc clamped to the wood surface. In general, stakes jet treated with ACA performed very well while those jet treated with pentachlorophenol performed

poorly except at very high retentions. All of the untreated controls were badly decayed and removed at the end of five years exposure. Table 1 summarizes the results of the ACA treatments and thirteen year decay ratings, and Table 2 summarizes the corresponding pentachlorophenol information. The test was discontinued at year thirteen because of the pending sale of the test site land.

ACA retentions in western hemlock tended to be quite high and penetration results met AWPA Standard C2 requirements. It was found that reducing the solution concentration and reducing the nozzle pressure resulted in lower retentions while maintaining satisfactory penetration. The thirteen year decay ratings showed complete absence of decay at assayed retentions of 0.22 - 1.29 pcf (3.5 - 20.6 kg/m^3).

ACA retentions in Douglas-fir tended to be somewhat lower than western hemlock under similar treating conditions. Preservative penetration was somewhat low and did not meet the requirements of AWPA Standard C2. The thirteen year decay ratings again showed complete absence of decay at assayed retentions of 0.09 -0.87 pcf (1.4 - 13.9 kg/m^3).

Both ponderosa pine sapwood and heartwood were successfully treated with ACA. The mean assayed retention in heartwood was slightly below normal ground contact retention, but the penetration exceeded 0.4 in. (10 mm) in all cases. The thirteen year decay ratings showed complete absence of decay at assayed retentions of 0.17 - 0.70 pcf (2.7 - 11.2 kg/m^3).

The pentachlorophenol treatments showed the same retention trends in the three species as did the ACA treatments. However, the thirteen year decay ratings were poor, indicating that satisfactory preservative distribution was lacking. The only exceptions were jet treatments using a 40 percent pentachlorophenol concentrate. These treatments gave very high retentions but resulted in excellent decay resistance.

A group of ten ACA treated Douglas-fir stakes were analyzed for preservative gradient and distribution after removal from the test plot. These ten stakes had all been treated submerged in preservative solution but at three different nozzle pressures. The ten stakes were divided into a high pressure group (6 stakes) and a low pressure group (4 stakes) for purposes of analysis. Table 3 shows the preservative gradient in the outer 0.8 in. (20 mm) zone in 0.2 in. (5 mm) increments.

The gradient for the high pressure group is not unlike that seen for conventional vacuum/pressure treatments. The gradient results for the low pressure group are skewed by the presence of high levels of preservative in wood defects in two of the stakes. Table 4 shows retention analysis comparisons of the jet hole areas and the areas between rows of jet holes. There appears to be little difference between the two areas in the high pressure group, but in the low pressure group there is a suggestion of higher retentions in the jet hole area.

Preservative distribution was also analyzed visually in the same ten Douglas-fir stakes. A section of each stake was planed to a depth of 0.2 in. (5 mm) on one face, and to a depth of 0.4 in. (10 mm) on the other face. The presence of preservative was visualized by application of chrome azurol S indicator. There was excellent preservative continuity at a depth of 0.2 in., but it was discontinuous at a depth of 0.4 in. This effect is more noticeable in the low pressure group than in the high pressure group. These results parallel the penetration measurements made on the cut ends. It appears that closer spacing of the rows of jet holes and/or higher pressures would be required to gain penetration results meeting AWPA Standard C2.

4.0 CONCLUSIONS

Western hemlock and ponderosa pine lumber can be successfully treated with ACA to meet AWPA Standard C2 requirements using high pressure jet treatment. Good thirteen year stake test results indicate satisfactory preservative distribution.

Jet treatment of Douglas-fir produced required retentions, but penetration did not meet the 0.4 in. (10 mm) requirement of Standard C2. Closer spacing of the rows of jet holes and/or higher pressures will be required for increased penetration.

Oilborne pentachlorophenol jet treatments gave good preservative uptake, but poor stake test performance indicates poor preservative distribution.

Waterborne ACA jet treatments give better preservative distribution than oilborne pentachlorophenol jet treatments. Diffusion of the waterborne preservative is the most probable reason for its increased distribution from the point of entrance and regions of initial mass distribution (Figure 2).

Jet treatment by virtue of its ability to inject preservative treatment beneath the surface of the wood should be an excellent method of treating green, high moisture content wood with waterborne, diffusible preservatives. This would eliminate one drying step in the treating process and assure treatment uniformity by diffusion of the preservative.

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Table 1

ACA Jet Treatments

Species	Preservative Concentration (%)	Treatment Method*	Nozzle Pressure (psi)	Weight Gain Retention (PCF)	S.D.	Assayed Retention (PCF)	S.D.	Penetration Percent of Stakes >0.4 in.	Total Number of Stakes	Average Decay Grade**
Western Hemlock	20	D	57.000	1.07	0.08	0.75	0.41	83	6	10
	20	D	48.000	1.46	0.12	0.85	0.27	86	7	10
	10.5	D	57.000	0.67	0.13	0.62	0.24	90	10	10
	10.5	U	42.000	1.29	0.26	0.83	0.12	100	6	10
	10.5	U	54.000	0.96	0.29	0.56	0.11	100	5	10
	10.5	U	33.000	0.54	0.10	0.48	0.24	100	4	10
Douglas-fir	10.5	D	54.000	0.58	0.10	0.58	0.18	46	13	10
	10.5	U	42.000	0.89	0.10	0.61	0.09	60	5	10
	10.5	U	54.000	0.90	0.08	0.39	0.10	57	6	10
	10.5	U	33.000	0.43	0.01	0.20	0.14	0	4	10
Ponderosa Pine										
- Sapwood	10.5	D	60.000	1.11	0.23	0.52	0.12	100	4	10
- Heartwood	10.5	D	60.000	0.65	0.11	0.37	0.20	100	4	10

* D = Treatment performed by firing jet through a disc clamped to wood surface.
U = Wood piece submerged in treating solution and the jet fired through the solution.
Rows of jet holes at 2 in. longitudinal spacing in both methods.

**AWPA Standard M7, thirteen year results.

Table 2

Pentachlorophenol Jet Treatments

Species	Preservative Concentration (%)	Solvent	Treatment Method[a]	Nozzle Pressure (psi)	Weight Gain Retention (PCF)	S.D.	Total Number of Stakes	Average Decay Grade[c]
Western Hemlock	10	Diesel	D	54,000	0.27	0.14	4	3.8
	40	None	D	54,000	1.6		2	10
	25	Diesel	D	54,000	0.68	0.13	4	7.5
	10	Diesel	U	48,000	0.43	0.06	4	4.0[d]
	10	Methylene Chloride	D	54,000	0.67	0.23	4	5.5
	20	Methylene Chloride	U	39,000	1.03		2	5.5
Douglas-fir	10	Diesel	D	54,000	0.42		4	7.0[d]
	40	None	D	54,000	2.35		2	10
	25	Diesel	D	54,000	0.68	0.17	4	7.8
	10	Diesel	U	48,000	0.23	0.04	4	5.3[d]
	10	Methylene Chloride	D	54,000	0.50	0.06	2	5.5
	20	Methylene Chloride	U	39,000	0.74		2	4.0[d]
Ponderosa Pine								
- Sapwood	20	Diesel	D	60,000	0.87	0.14	5	3.0[e]
- Heartwood	20	Diesel	D	60,000	0.47	0.07	7	2.9[e]
- Sapwood	20	Diesel	D[b]	60,000	1.17		1	7.0[d]
- Heartwood	20	Diesel	D[b]	60,000	0.60	0.11	4	4.8

[a] D = Treatment performed by firing jet through a disc clamped to wood surface.
U = Wood piece submerged in treating solution and the jet fired through the solution.
Rows of jet holes at 2 in. longitudinal spacing in both methods.

[b] Rows of jet holes at 1 in. longitudinal spacing.

[c] AWPA Standard M7, thirteen year results.

[d] Includes ratings of one or more stakes removed after 9 years due to decay.

[e] Includes ratings of one or more stakes removed after 5 years due to decay.

Table 3

Preservative Gradient in Douglas-Fir

Number of Stakes	Treatment Pressure (psi)	Mean ACA Retentions (PCF)*			
		0-0.2 in.	0.2-0.4 in.	0.4-0.6 in.	0.6-0.8 in.
6	42,000-54,000	1.12 ± 0.35	0.80 ± 0.36	0.16 ± 0.11	0.04 ± 0.07
4	33,000	0.42 ± 0.10	0.40 ± 0.15	0.19 ± 0.07	0.49 ± 0.88

* Borings were taken from face of stakes between rows of jet holes and above ground line.

Table 4

Longitudinal Preservative Distribution in Douglas-Fir

Number of Stakes	Treatment Pressure (psi)	Mean ACA Retentions (PCF)*	
		Borings Taken on Jet Holes	Borings Taken Between Jet Holes
6	42,000-54,000	0.38 ± 0.13	0.42 ± 0.13
4	33,000	0.41** ± 0.18	0.20** ± 0.14

* Borings were taken from edge of stakes above ground line.

**A T-test shows significant difference at the 77% probability level.

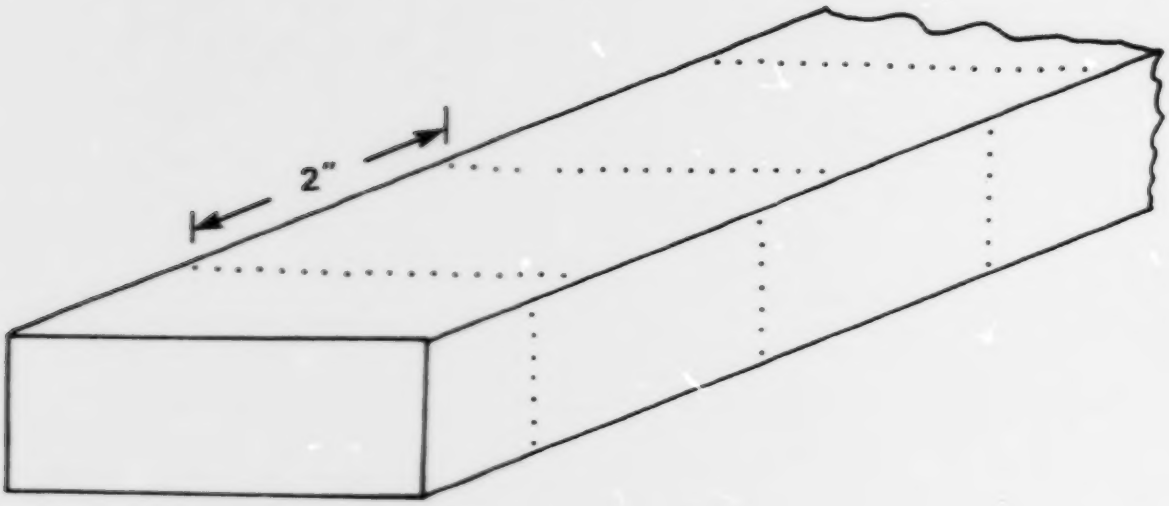

Figure 1 Typical jet treating pattern for a 2 x 4.

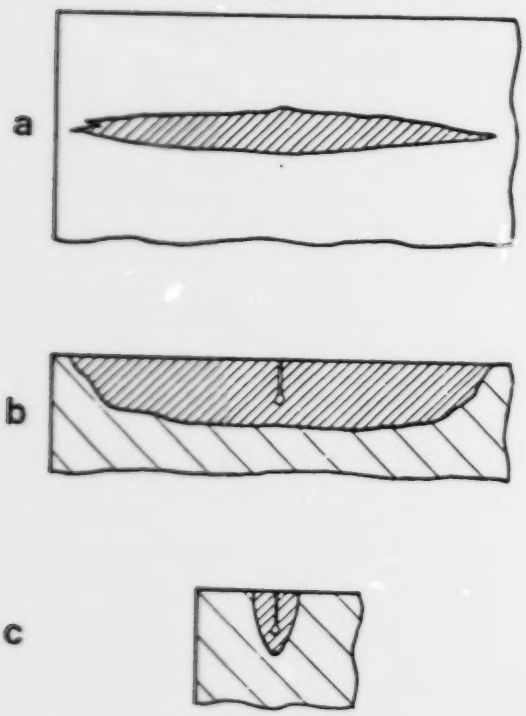

Figure 2 Treated wood in vicinity of a single jet entrance hole in solid wood: (a) surface view, (b) distribution along the grain, (c) distribution across grain.

ENHANCED PRESERVATIVE TREATMENT OF CANADIAN LUMBER THROUGH NEEDLE INCISING

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SUMMARY

Kiln dried eastern black spruce, jack pine (from Quebec and Saskatchewan), lodgepole pine (from Cranbrook and Quesnel), western white spruce and coastal Douglas-fir lumber was acquired for the study from sawmills or retail outlets. After processing to produce matching samples, one group of boards was shipped to Germany for needle incising. Two patterns were used. The first was the needle incising pattern used normally by the firm owning the machine. The second was a denser pattern having a reduced longitudinal separation of incisions. The conventionally incised material was processed by a local company near Vancouver. All the boards were returned to Forintek for treatment with chromated-copper-arsenate (CCA) and ammoniacal copper arsenate (ACA).

Evaluation of the penetration showed that average penetrations were greater in the conventionally incised boards due to the differences in the incision depths produced by the two processes. Comparison of the relative penetration with the relative incision depths showed that the needle incising was slightly more effective in improving penetration. This result was more pronounced when the percent integrity of the treated zone was measured.

The needle incising generally produced a more uniform treatment with CCA, but the enhanced penetration recorded for the ACA masked any improvement of the incising process. It was concluded that the needle incising pattern should be modified by increasing needle length to produce incisions with a depth of 10 mm, and that the longitudinal separation of incisions should be reduced to ca 24 mm to ensure consistent treatment of the wood species studied here.

The preservative retentions achieved by the higher density needle incising pattern and the conventional incising were above that required for lumber used in ground contact.

Evaluation of the fibre damage associated with incisions produced by the needle and conventional incisors, suggested that the needle process produced much less fibre damage, and could reduce strength losses to one or two percent, assuming that strength losses correlate directly with fibre damage produced by incising.

1.0 INTRODUCTION

Needle incising significantly improved the preservative treatment of lodgepole pine (**Pinus contorta** Dougl.) and western white spruce [**Picea glauca**, (Moench) Voss.] lumber, although it was also concluded that further refinement of the incising pattern was required (Ruddick, 1986). To develop the more extensive data base necessary to identify the enhancement in the treatment of Canadian lumber by needle incising, a second study was designed, which utilized wood from three different regions of Canada. The wood species investigated were lodgepole pine, jack pine (**Pinus banksiana** Lamb.), eastern black spruce (**Picea mariana** B.S.P.), western white spruce and coastal Douglas-fir [**Pseudotsuga menziesii** (Mirb) Franco].

The objectives of this 'follow-up' study were twofold. Firstly it would identify the improvement in the treatment achieved using a more dense needle incising pattern. A second objective was to compare the treatment quality produced by the two waterborne preservatives, chromated-copper-arsenate (CCA) type C, and ammoniacal copper arsenate (ACA). As in the initial study, all incising was carried out using commercial equipment.

2.0 MATERIALS AND METHOD

2.1 SAMPLE PREPARATION

Over 380 kiln dried boards, nominally 5 x 10 cm and 4.9 m in length, were purchased from sawmills or retail outlets for the investigation. Preference was given to lumber having a high heartwood content since sapwood, being easily treated, would mask the effects of incising. Douglas-fir lumber was purchased from a local supplier in Surrey, B.C. The lodgepole pine was obtained from two sawmills (Crestbrook Forest Industries Ltd., Cranbrook and West Fraser Mills Ltd., Quesnel) both in the interior of B.C. The latter sawmill also provided the western white spruce. Jack pine lumber was acquired from two sources, Saskatchewan Forest Products Corporation, Saskatchewan and Goodfellow Lumber Ltd., Montreal, Quebec, while the black spruce was purchased from a local retailer in Ottawa, Ontario.

Upon arrival at Forintek, each board was processed to produce 2.3 m long matching samples for incising using the needle and conventional incising processes. With the exception of the black spruce and jack pine from eastern Canada, a small section, ca 0.3 m, was retained to allow determination of the specific gravity and confirmation of the species identity. During this first stage of sample preparation a few boards were rejected as being unsuitable, principally because of excessive sapwood

content. After numbering all of the boards, they were divided into two groups for incising by the two processes. Those to be needle incised were shipped by air to J.H. Benker KG, Hörgertshausen in West Germany. The needle incisor was the original prototype and has been in commercial operation for several years. It can only incise one face of the board at a time, with a throughput of ca 10 - 15 m/min. Two incising patterns were used. The first was identical to that employed in the earlier study (Ruddick, 1986) and is shown in Figure 1. The second pattern had twice the number of incisions per square meter (27,776), with a longitudinal separation between incisions of 36 mm. The lateral spacing remained unchanged. The denser incising pattern was achieved by incising each board twice, taking care to offset the second pattern by half of the pattern repeat distance. With the exception of the western white spruce and lodgepole pine lumber, for which the original (single) needle incising pattern had already been shown to be inadequate, approximately equal numbers of boards were incised with each pattern (Table 1). For the white spruce and lodgepole pine, all samples were doubly incised.

Although improvement in the needle incising pattern was achieved in this study, the incision depth could not be improved, since the only available needles produced incisions with a depth of ca 8 mm. The boards to be incised using the conventional process were shipped to B.C. Clean Wood Preservers Ltd. at Surrey, B.C. where they were incised with a staggered pattern (Figure 2). During the incising process the roller pressure was increased to ensure full 10 mm penetration by the incising teeth. All the incised test material was then returned to Forintek for further processing prior to treatment.

Each of the 2.3 m long incised boards was then sawn in two to produce 1.0 m matching samples for treatment with CCA and ACA. A small section, 0.3 m, was retained for reference purposes. In order to elminate end penetration, the ends of each sample were sealed with two coats of an epoxy resin. The boards were then sorted into groups for treatment.

2.2 PRESERVATIVE TREATMENT

To minimize the effects of treatment, needle and conventionally incised boards were treated in the same charge. A full cell process was used, consisting of an initial 30 minute vacuum of -97 kPa and a pressure of 1040 kPa which was maintained for 15 hours. The maximum pressure was attained in stages over 20 minutes. No final vacuum was employed. All treating solutions were at ambient temperature, ca 20°C. The CCA solution strength ranged from 1.6 to 1.8% while the ACA solution concentration was 1.96%.

2.3 POST-TREATMENT SAMPLE PROCESSING

After treatment, all samples were allowed to air dry in the laboratory prior to processing. A small section (ca 10 cm long) was then removed from the central region of each board for determination of the penetration and retention characteristics of each treatment. After oven drying it was processed as described previously (Ruddick, 1986).

The preservative penetration was measured in two ways. In the first, a simulated core provided a single estimate of penetration, in the manner required by the Canadian wood preservation standard (CSA 080, 1985).

The second measurement was an estimate of the percent integrity of the outer shell of treated wood at preselected depths from the surface. It was developed by routing out a channel of specified width and depth across the whole sample width and measuring the percent of treated wood in the routed area. Since the incisions produced by the needle and conventional processes were of different depths, two sampling depths from the board surface were chosen. The first, 5 mm was easily achieved by both processes. The second measurement was made at the limit of the incision and was 8 mm (7 mm for the Douglas-fir) for needle incised material and 10 mm for conventionally incised boards. All penetration assessments were made using the standard chrome azurol S indicator, which reacts with the copper to produce a dark blue color. The preservative content was determined for each board using material collected from sampling assay zones specified in the Canadian standard. The sawdust was analyzed using energy dispersive x-ray spectrometry (AWPA A9-86).

To determine the impact of the needle and conventional incising on the quality of the treated board, the amount of damaged wood associated with each incising process was assessed by cross cutting each board through the centre of a row of incisions. A grid was laid over the cross section and the damaged area associated with each incision was assessed visually. The results were averaged for three boards for each wood species.

3.0 RESULTS AND DISCUSSION

3.1 PRESERVATIVE PENETRATION

The results of the preservative penetration assessment are summarized in Table 2. It is important to note that the average penetrations shown are based upon a single random assessment of penetration in each test sample. Where uniform treatments are achieved, this value will provide a good indication of the penetration. However, where the integrity of the treated zone is incomplete, the results may not correlate well with the improvement

in the treatment. Inspection of the data showed that the use of a higher density of incisions generally improved the penetration. With the exception of black spruce all needle penetration values were higher for the doubly incised material. However improvements were small and with the variability in the treatments, differences were not found to be significant, except for Douglas-fir where the improvement was significant at the 95% level. The subsequent discussion in the paper will focus on the data produced by the denser needle incising pattern.

Since the depth achieved by the conventional incising process of 10 to 11 mm was greater than the 7 mm needle incision depth, the preservative penetrations would be expected to reflect this difference, and they do. To determine whether the improvement in preservative penetrations resulting from the two incising processes were equivalent, the ratios of the CCA and ACA penetrations were compared with the ratios of the incision depths (Table 3). Where the needle incising is more effective than the conventional incising process (used in this study) for improving the preservative penetration, the penetration ratio will be greater than the ratio of the incision depths.

The results shown in the table indicate that for CCA the degree of improvement achieved with needle incising was slightly greater than that achieved with conventional incising. Two notable exceptions were the lodgepole pine (Cranbrook) and the Douglas-fir, where the relative effectiveness of the incising processes was similar.

When a similar comparison was made for the ACA penetrations, the degree of improvement produced by needle incising was less pronounced than that found for CCA. Four of the species groupings (jack pine from Saskatchewan, lodgepole pine from both sources and Douglas-fir) showed no difference between the relative improvement produced by the two incising processes. This observation is consistent with conclusions reported by other researchers that the ammoniacal based preservatives display enhanced penetration characteristics, which in this study tended to mask differences in the effectiveness of the incising processes. Thus although the absolute magnitude of the preservative penetrations achieved in conventionally incised material were greater than those present in the needle incised lumber, this difference is due primarily to differences in incision depth.

A more useful comparison of the two processes is gained from the information on the integrity of the treated shell, as measured by the percent of treated wood at selected sampling depths. The results of the analyses of percent penetration at 5 mm is shown in Table 4. For the CCA treated boards, it is clear that the higher density of incisions has improved the integrity of the treated zone.

Evaluation of the data shows that the original needle incising pattern is not as effective as either the more dense needle incising pattern or the conventional incising, in producing a uniform treatment. However based upon the 5 mm data the more dense needle incising pattern and the conventional incising produced equivalent treatments with either the CCA or the ACA. There was even here a suggestion that the ACA treatment was superior, although this finding was only significant for the black spruce, the lodgepole pine from Cranbrook and the Douglas-fir.

The determination of the percent of treated wood at the greater depth (8 mm for needle incising and 10 mm for conventional incising) showed more clearly the improvement achieved by reducing the longitudinal spacing of the needle incising pattern to 36 mm, to increase the incision density (Table 5). Where both needle incising patterns were used, the improvements in the percentages of treated wood in the doubly incised material were all significant at the 95% level or greater.

Comparison of the percent penetration achieved by the more effective needle incising pattern with the results for the matched conventionally incised material revealed that the needle incising generally produced a more uniform treatment although in many cases the percent integrity of the treated shell fell far below that required to ensure a consistent treatment to standard requirements. The higher percentages for the CCA-needle incised lumber were recorded for the eastern black spruce and jack pine from both sources, with conventional incising producing more effective CCA treatment in Douglas-fir and equivalent treatments in the jack pine from Saskatchewan, the western white spruce and the lodgepole pine from both sources. However both incising processes failed to overcome the extreme refractory nature of the lodgepole pine from Cranbrook, for which the percentages of treated wood were extremely low. Indeed combining the data for both preservatives and incising processes, lodgepole pine appeared to be one of the most difficult wood species to treat.

The results for the ACA-treated lumber, confirmed the superior penetration achieved with this preservative. Consequently, comparison of the effectiveness of the more compact needle incising pattern (with the reduced longitudinal spacing of 36 mm) with that achieved by the conventional incising process, showed them to be equivalent. The percentages of the ACA treated wood at the 8 or 10 mm depths were not significantly different. Thus it may be concluded from this study that with ACA, the higher density needle incising pattern and conventional incising produced similar improvements in the treatment of refractory sawnwood.

3.2 PRESERVATIVE RETENTION

The CCA and ACA solution concentrations were both less than 2% (w/w), which is slightly lower than values which may be used commercially.

Nevertheless, the average retentions for all treatment groups (with one exception) exceeded the 6.4 kg/m^3 required by the Canadian wood preservation standard for wood used in ground contact (CSA 080.2, 1985). The one exception was the jack pine from Saskatchewan which was incised with the less effective needle incising pattern and treated with ACA. However, for the groups incised with the more effective needle incising pattern, all the retentions exceeded the Canadian standard requirement (Table 6).

Since relatively large amounts of sample were needed to produce a single assay for each board, the collection of wood adjacent to incisions was unavoidable. Consequently, the results for the conventionally incised boards reflect the presence of precipitated preservative trapped in the fissures adjacent to the incisions. This was not a problem with the needle incised material, which did not induce damage in the tissues adjacent to the incisions. Of more practical significance is the observation of the excellent retentions achieved, particularly for the boards processed with the higher density needle incising pattern and conventional incising process. With the exception of the needle incised black spruce and lodgepole pine from Cranbrook, all the CCA retentions exceeded even the 9.6 kg/m^3 required for preserved wood foundation material. The ACA retentions were generally lower than those found for the corresponding treatment. This may indicate some post-treatment diffusion, since the penetrations achieved by the ACA were generally superior to those recorded for the CCA treatment.

3.3 FIBRE DAMAGE

One of the obvious benefits arising from needle incising is the lack of surface degrade produced by the process. Thus after treatment the incisions are essentially invisible. It is this lack of fibre damage associated with the incision which also results in the extremely low reduction in strengths associated with the process (Burmester, 1983). To determine the relative amounts of damaged fibre, samples were cross cut through the centre of the incision and the cross-sectional area associated with each incision type was measured. For the needle incision an average cross-sectional area of fibre damage of less than 1.5 mm^2 was determined, while for the conventional incision the fibre damage ranged from 15 mm^2 in western white spruce to 30 mm^2 in black spruce. The average value for all wood species groups was calculated to be ca 20 mm^2. Assuming that the conventional incision is triangular in shape along its length and uniform in cross-section the amount of damaged fibre associated with each incision was determined to be approximately 140 mm^3. This may be compared with a value of 3 for a needle incision. But since there are many more needle incisions than conventional incisions, this factor should also be considered.

The conventional incising pattern used in the study created 4,433 incisions per m^2, while the needle incision densities were 13,888 and 27,776 per m^2. The volumes of damaged fibre associated with each of the three patterns is then calculated to be 621 cm^3/m^2 (conventional incising pattern), 27 cm^3/m^2 (original needle incising pattern) and 54 cm^3/m^2 (higher density needle incising pattern). Thus the needle incising process could produce approximately one tenth of the fibre damage produced by conventional incising, which presumably will also translate in a significant reduction in the loss in strength resulting from the incising process. Although the strength loss associated with high density staggered incising patterns is not available, values of more than 20% have been reported by Nunomura and Saito (1983) on 8.5 cm^2 Douglas-fir incised with 6,600 incisions per square meter. This would suggest that the loss in strength produced by needle incising should be in the order of 1 to 2%, assuming that it correlates directly with the amount of fibre damage. This conclusion is in good agreement with the results reported by Burmester (1983) of no detectable loss in strength when using the original needle incising pattern having 13,888 incisions per square meter.

3.4 SPACING OF INCISIONS FOR EFFECTIVE TREATMENT

One of the obvious conclusions from this investigation is that the original longitudinal separation of incisions of 72 mm is too great to ensure complete integrity of the treated zone. Indeed based upon the results for CCA-treated needle incised boards, even a 36 mm spacing appears to be too long. Measurement of the longitudinal penetration in some samples suggested that the incisions should not be separated by more than 24 mm to ensure uniform treatment. The lateral spacing of ca 9 mm between ranks of incisions appears to be adequate. These conclusions are supported by the results for the conventionally incised boards. In this case the longitudinal separation of ca 30 mm improved the treatment, but the 14 mm lateral separation between adjacent incisions was too great. If the current industrial trend to produce fine incisions using thin toothed incisors continues, the associated fibre damage with each incision will be reduced. This will necessitate reducing the lateral separation between incisions by at least 5 to 6 mm from the 14 mm used in this study.

4.0 CONCLUSIONS

Needle incising can improve the treatment of Canada's refractory wood species. However the existing needle incising pattern needs refinement. The two principal modifications required are an increased needle length to ensure incisions with 10 mm depth, and reduction of the longitudinal spacing of incisions from 72 mm to ca 24 mm. All wood species considered in this study would then have been adequately treated.

The conventional incising process produced greater average preservative penetrations due to its greater incision depth. Even so, some refinement of the pattern was considered necessary to provide treatments which consistently achieved the Canadian standard requirements for the lumber species utilized in the investigation.

Strength losses estimated from the fibre damage associated with the needle and conventional incising processes, suggested that those associated with the needle incising could be approximately ten times less than those resulting from the conventional incising process used in this study. The latter could be reduced through the use of a thin blade incisor.

5.0 RECOMMENDATIONS

Needle incising of lumber has been demonstrated to greatly improve treatment of lumber produced from Canada's refractory wood species. This improvement is achieved with no surface degrade. Commercialization of this technique will lead to high quality sawnwood products. It is therefore recommended that industry be encouraged to further develop the technology to meet North American treating requirements.

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Table 1

Number of Boards Incised With Each Pattern

Wood Species	Needle		Regular
	Single	Double	
Eastern black spruce	30	28	58
Jack pine (Quebec)	27	23	60
Jack pine (Saskatchewan)	25	25	50
Lodgepole pine (Cranbrook)	--	40	40
Lodgepole pine (Quesnel)	--	24	24
Western white spruce	--	30	30
Douglas-fir	26	33	59

Table 2

Penetration Results for Needle and Conventionally Incised Lumber Pressure Treated with CCA and ACA

Wood Species	Needle Incising Pattern	CCA Penetration		ACA Penetration	
		Needle	Conventional	Needle	Conventional
Eastern black spruce	single	9.6 (3.1)	10.9 (2.6)	12.3 (2.6)	13.1 (1.9)
	double	8.8 (2.8)	9.9 (2.5)	11.9 (2.1)	13.3 (2.4)
Jack pine (Quebec)	single	11.1 (3.6)	11.1 (3.6)	10.4 (2.6)	13.0 (2.0)
	double	12.2 (3.5)	11.6 (3.6)	12.0 (2.6)	13.0 (2.2)
Jack pine (Saskatchewan)	single	10.7 (3.2)	11.0 (3.0)	9.8 (2.8)	12.0 (1.7)
	double	11.3 (3.0)	11.8 (3.0)	10.2 (1.7)	12.5 (2.1)
Western white spruce	double	10.0 (2.5)	11.0 (3.1)	13.2 (2.6)	14.1 (1.9)
Lodgepole pine (Cranbrook)	double	7.9 (2.4)	9.4 (2.2)	9.3 (1.1)	11.7 (2.0)
Lodgepole pine (Quesnel)	double	11.2 (3.6)	12.4 (2.8)	10.2 (1.9)	12.4 (2.0)
Douglas-fir	single	6.8 (4.5)	10.4 (4.2)	9.4 (2.5)	13.7 (2.2)
	double	9.6 (2.9)	11.8 (4.8)	10.3 (2.7)	13.4 (2.1)

( ) = Standard deviation

Table 3

Comparison of the Ratio of Needle and Conventional Incision Depth with the Ratios of the Preservative Penetrations

Wood Species	Ratio of Incision Depth Needle/Conventional	Ratio of Preservative Penetration* CCA Needle/Conventional	Ratio of Preservative Penetration* ACA Needle/Conventional
Eastern black spruce	0.80	0.88	0.89
Jack pine (Quebec)	0.80	1.05	0.92
Jack pine (Saskatchewan)	0.80	0.95	0.75
Western white spruce	0.80	0.90	0.93
Lodgepole pine (Cranbrook)	0.80	0.84	0.82
Lodgepole pine (Quesnel)	0.80	0.90	0.79
Douglas-fir	0.75	0.81	0.76

* Based on needle incising data for denser pattern.

Table 4

Percentage of Treated Wood at a Sampling Depth of 5 mm

Wood Species	Needle Incising Pattern	CCA(%) Treated Wood		ACA(%) Treated Wood	
		Needle	Conventional	Needle	Conventional
Eastern black spruce	single	78	94	100	100
	double	91	90	100	100
Jack pine (Quebec)	single	91	97	95	100
	double	96	97	100	100
Jack pine (Saskatchewan)	single	88	96	94	99
	double	96	96	99	99
Western white spruce	double	96	95	100	100
Lodgepole pine (Cranbrook)	double	87	89	100	100
Lodgepole pine (Quesnel)	double	99	99	100	100
Douglas-fir	single	65	87	91	100
	double	83	88	98	100

Table 5

Percentage of Treated Wood at Sampling Depths of 8 mm (Needle Incised Boards) and 10 mm (Conventionally Incised Boards)

Wood Species	Needle Incising Pattern	CCA(%) Treated Wood		ACA(%) Treated Wood	
		Needle	Conventional	Needle	Conventional
Eastern black spruce	single	61	49	99	100
	double	74	38	100	93
Jack pine (Quebec)	single	70	56	75	88
	double	84	64	92	88
Jack pine (Saskatchewan)	single	67	72	63	91
	double	77	73	85	91
Western white spruce	double	66	68	100	100
Lodgepole pine (Cranbrook)	double	49	37	88	92
Lodgepole pine (Quesnel)	double	64	65	80	86
Douglas-fir	single	40	73	77	95
	double	64	76	94	99

Table 6

Retention (kg/m^3) of CCA and ACA-Treated Lumber

Wood Species	Needle Incising Pattern	CCA		ACA	
		Needle	Regular	Needle	Regular
Eastern black spruce	single	9.0	11.3	7.1	7.9
	double	8.4	10.0	6.7	7.7
Jack pine (Quebec)	single	12.4	12.9	6.7	9.1
	double	13.9	13.5	8.3	10.0
Jack pine (Saskatchewan)	single	9.0	11.4	5.7	8.0
	double	10.9	12.0	6.5	8.5
Western white spruce	double	10.3	11.4	9.3	10.3
Lodgepole pine (Quesnel)	double	10.6	12.1	8.7	10.2
Lodgepole pine (Cranbrook)	double	8.2	9.8	6.4	7.8
Douglas-fir	single	9.7	15.2	9.4	14.9
	double	11.8	15.3	10.5	14.7

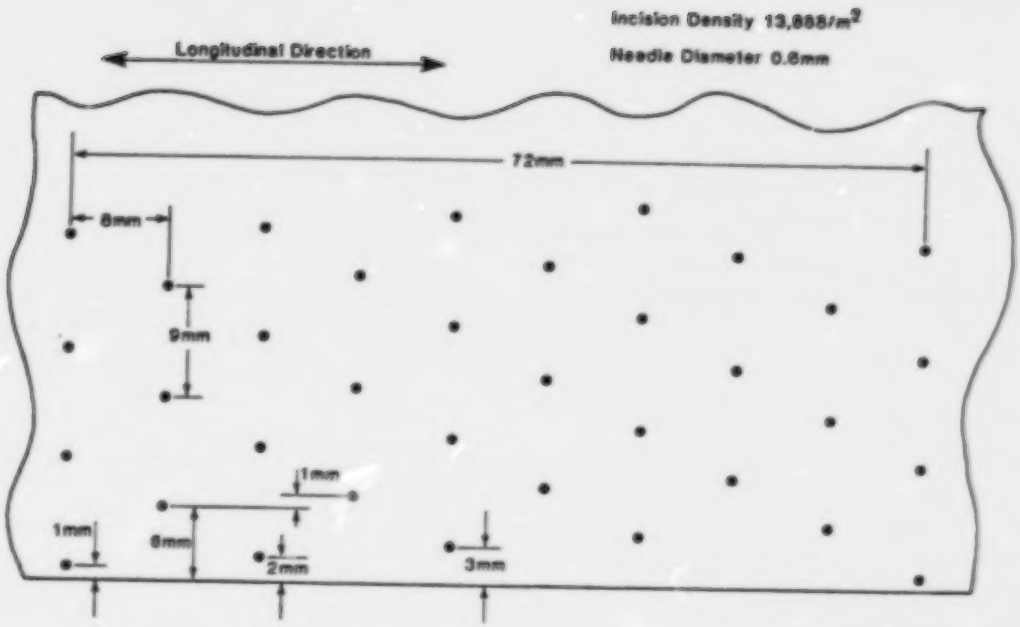

Figure 1 The needle incising pattern.

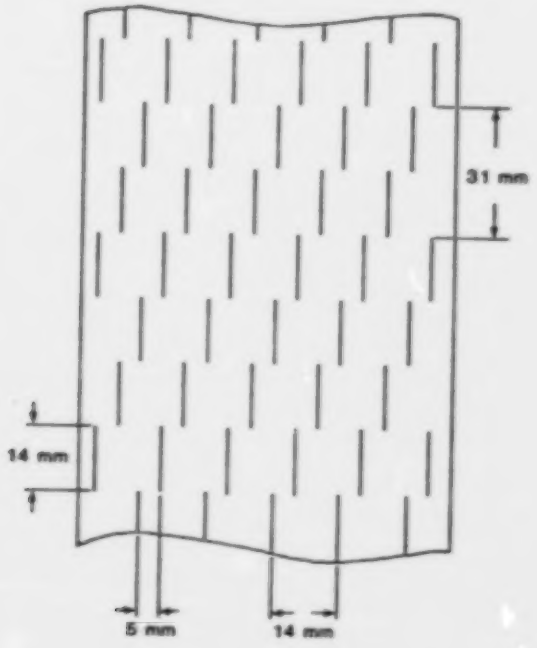

Figure 2 Commercial staggered incising pattern.

CURRENT STATE OF THE ART OF INCISING IN JAPAN

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1.0 INTRODUCTION

Japan is said to be a forest country and 66% of the land is covered with forests. Nevertheless, we imported about 59 million cubic metres of wood last year (1985) which is 64.4% of total consumption of 92 million cubic metres. Although house construction in Japan has tended to show a declining growth in recent years, about 1.2 million houses were built last year and of these 48% were constructed from wood. This means that we are using not only a large amount of timber, but also many different kinds of timber, for house construction. And most of the timbers are refractory to pressure treatment. Table 1 shows the main timber species used for house structural members in Japan.

2.0 BIOLOGICAL HAZARDS FOR TIMBER IN JAPAN

Japan is a series of long narrow islands extending from about 45° to 25° north latitude, which means it is located much farther south than Canada. It is very hot and humid in summer and timbers are susceptible to decay if they are not properly preserved. Termite infestation is also severe almost all over the country. Fifteen species of termite are found, but two species, **Reticulitermes speratus** and **Coptotermes formosanus** are most important. As shown in Figure 1, the **Reticulitermes** covers the whole country, except the northern part of Hokkaido, while **Coptotermes**, a very fierce termite, infests the southern parts (dark colored) of Japan. Therefore, structural timber must be protected from these hazards regardless of its location in Japan.

3.0 HISTORICAL PERSPECTIVE TO JAPANESE INCISING

There are many national Standards for wood preservation such as JIS (Japanese Industrial Standards) and the JAS (Japanese Agricultural Standards), and they are similar to those of Canada (CSA) or the U.S. American Wood Preservers' Association (AWPA).

Foundation wood sills are one of the structural members most susceptible to decay and termite attack and Hinoki, (**Chamaecyparis obtusa** Endl.), a naturally durable species, has long been used for this purpose. However, Hinoki became very expensive due to its short supply. Fortunately western hemlock square timbers treated with chromated-copper-arsenate (CCA) were introduced onto the market.

As shown in Figure 2, quality control sample borings were originally taken 30 cm apart from one end of the board according to a former JAS standard. The standard required that the preservative penetration must be a minimum of 80% of half the depth of the timber.

However, two problems arose. Home builders wanted to use local timbers as much as possible, but many of the Japanese species failed to meet the 80% penetration requirement. Another problem was the mid-point penetration. It was sometimes found that very poor penetration occurred at the centre of the board even though they met the 80% penetration when the borings were removed 30 cm from one end, as required under the old standard. The JAS Committee discussed these problems and proposed new requirements for penetration as shown in Figure 2b. In the cross cut samples taken at mid-point of length, the minimum penetration is 80% of the sapwood and 80% of the outer 10 mm zone of heartwood.

In response to this proposal, the Japanese wood preserving industries decided to introduce incising techniques as the most practical solution to ensuring conformance to the new standard.

4.0 DEVELOPMENT OF INCISING

Initially, various basic investigations were made of the penetration characteristics of several incising techniques. Figure 3 shows penetration patterns achieved with various types of incisor including conventional roller incisors with chisel or knife-shaped teeth, needles, etc. having thicknesses of 2 to 4 mm (1). It was found that the chisel type was better than the use of knives and needles, but the difference was not very great.

Figure 4 shows penetration patterns of five different wood species incised to depths of 5 mm (left) and 10 mm (right) with a 4 x 10 x 10 mm incising tooth (1). The chisel tooth provided a somewhat better penetration than the knife in both depth and spread of preservative (Figure 5) (1). However, chisel type blades were avoided because the severe degrade caused by the incisions on timber faces was considered to be unacceptable to home builders.

5.0 EFFECTS OF INCISING

Hundreds of timbers were examined to determine if it was possible, by using incising, to achieve JAS level of penetration. Figure 6 shows the results of one such test. The net absorption (kg/m^3) of sixty pieces of western hemlock timber (10.5 x 10.5 x 400 cm) were plotted. The

average absorption of the non-incised group was 194 kg/m^3 and many pieces were below 100 kg/m^3. By comparison, the incised group, processed with an incision density of 2500 incisions/m^3 using 3 x 10 x 10 mm blades achieved an average absorption of 261 kg/m^3 and none was below 100 kg/m^3.

Figure 7 shows the penetrations recorded in the borings taken at the mid-point of the timber, from twenty pieces out of the sixty. Penetration of borings from non-incised lumber was quite poor, while those from the corresponding incised material almost all achieved 10 mm penetration.

When tested with end matched western hemlock square timber, all of the incised timber met the JAS standard, compared with only 40% of the non-incised group (Figure 8, Table 2).

Figures 9 to 18 show examples of penetration in the commonly used wood species in Japan. The four faces of each timber were sliced at 5 mm depth and diphenyl carbazide reagent was applied to aid penetration measurement. Western hemlock, domestic Sugi and Hinoki timber easily achieved the JAS penetration requirements. It was also found that Todomatsu (**Abies** sp.) timbers could be treated to the standard with little difficulty. However, Japanese spruce, Ezomatsu (**Picea** sp.) was difficult to penetrate. It is thought that with an increased density of incisions, a successful treatment can be achieved. In these figures, Douglas-fir gave better penetration with incising (compared to non-incised portions at corners), but this example seemed to be an exception. It is usually much less permeable.

It was reported to be very difficult to treat Japanese larch (Karamatsu) timber to the 80% penetration requirements of the JAS standard. Therefore, Douglas-fir and Karamatsu are grouped together in the third class treatment in JAS. This group requires only 20% penetration for the 10 mm heartwood zone.

6.0 INCISING MACHINES AND TYPICAL PATTERNS

Incising machines have been developed and marketed by several manufacturers in Japan. The machines differ in several aspects, including: the shape and size of blade; incision density; the incising pattern; the method of fixing teeth to drums; speed of operation; and the maximum and minimum timber cross sections which can be incised. Table 3 shows typical sizes of teeth and the incision densities used for three cross sections of timber, adopted by the three principal manufacturers of incisors. These patterns were tested, and were authorized on the basis that strength reductions would be less than 10%.

Figures 19 to 23 illustrate some of the Japanese incising machines. Two incisors, shown in Figures 19 and 20, are manufactured by Koshii Preserving Co. Ltd. The blades are 2.5 mm thick and the incising marks are not pronounced and are considered to be acceptable by most of the treaters (Figure 21). Two other incising machines, made by Fugi Kogyo Co. Ltd., are illustrated in Figures 22 and 23. The tooth dimensions are 4 x 10 x 10 mm.

7.0 MERITS OF INCISING AND CURRENT PRACTICES

The purpose of developing and utilizing incising is to maintain the high quality of pressure treated sawnwood required by the JAS, for as many timber species as possible. Almost all timber species can now be successfully treated to JAS standards with the aid of incising.

The distribution of CCA pressure treating plants in Japan is shown in Figure 24. Under the JAS quality timber scheme, the Japanese government authorizes and approves plants to put a JAS stamp of approval on the treated timber if it passes the JAS quality control inspections. JIS also has a similar quality control scheme, but the timber species are limited to western hemlock and Apitong. Currently 57 out of the 128 plants in Japan are authorized by JAS and JIS, and their distribution is shown in Figure 24.

Treating plants authorized by JAS must be equipped with incising machines. Besides the JAS authorized treaters, many other pressure plants are also using incisors and there are over eighty incising machines in use all over the country.

The merits of incising are summarized in Table 4. One of the key benefits in addition to improving the preservative penetration is the elimination of large checking in treated timbers (Figure 23).

8.0 FUTURE RESEARCH NEEDS

Problems still remain with current roller incisors, some of which are, poor corner penetration and inability to adequately penetrate very refractory species such as larch, mountain type Douglas-fir and imported spruces. Prefabricated building construction is becoming popular in Japan. How to incise and obtain deep penetration in the prefabricated timber is also a problem.

9.0 REFERENCE

(1) H. Sonobe, et al. 31st Convention of The Japan Wood Research Society.

Table 1

Main Timber Species Used

HOKKAIDO	DOMESTIC		
		TODOMATSU	Abies sachalinensis Fr. Schm.
		EZOMATSU	Picea jezoensis Carr.
		KARAMATSU	Larix Leptolepis Gord.
MAIN ISLAND SHIKOKU ISLAND KYUSHU ISLAND	DOMESTIC		
		SUGI	Cryptomeria japonica D. Don
		HINOKI	Chamaecyparis obtusa Endl.
	IMPORTED		
		WESTERN HEMLOCK	
		DOUGLAS FIR	
		WHITE FIR	
		SPRUCE	
		APITONG	

Table 2

Penetration Percentage in Outer 10 mm Zone

Not Incised				Incised			
No	absorp. kg/m³	penet. %		No	absorp. kg/m³	penet. %	
1	231	51	×	1	372	100	○
2	222	68	×	2	283	98	○
3	320	87	○	3	377	98	○
4	240	65	×	4	273	99	○
5	617	100	○	5	391	97	○
6	207	99	○	6	316	99	○
7	311	76	×	7	306	100	○
8	316	76	×	8	410	94	○
9	179	81	○	9	292	98	○
10	255	75	×	10	372	99	○
av.	290	78	PASS 40%	av.	339	98	PASS 100%

Table 3

Standard Incising Patterns

Maker	Size of Blade	Standard Pattern Numbers/㎡		
	Thick×Wide×Depth (mm)	Cross Section of Timber (mm)		
		40×90	85×85	10.5×10.5
A	2.5×10×10	3,400 4,500	4,500 (9,000)	4,500 (9,000)
B	3.8×10×10	3,463	4,848	4,848
C	4.0×10×10	4,834	4,834	4,834

Table 4

Merits of Incising

(1) Enable many species to meet JAS penetration requirements.

(2) More even surface penetration.

(3) Reduce pressure treatment time.

(4) Reduce seasoning time.

(5) Reduce large checking.

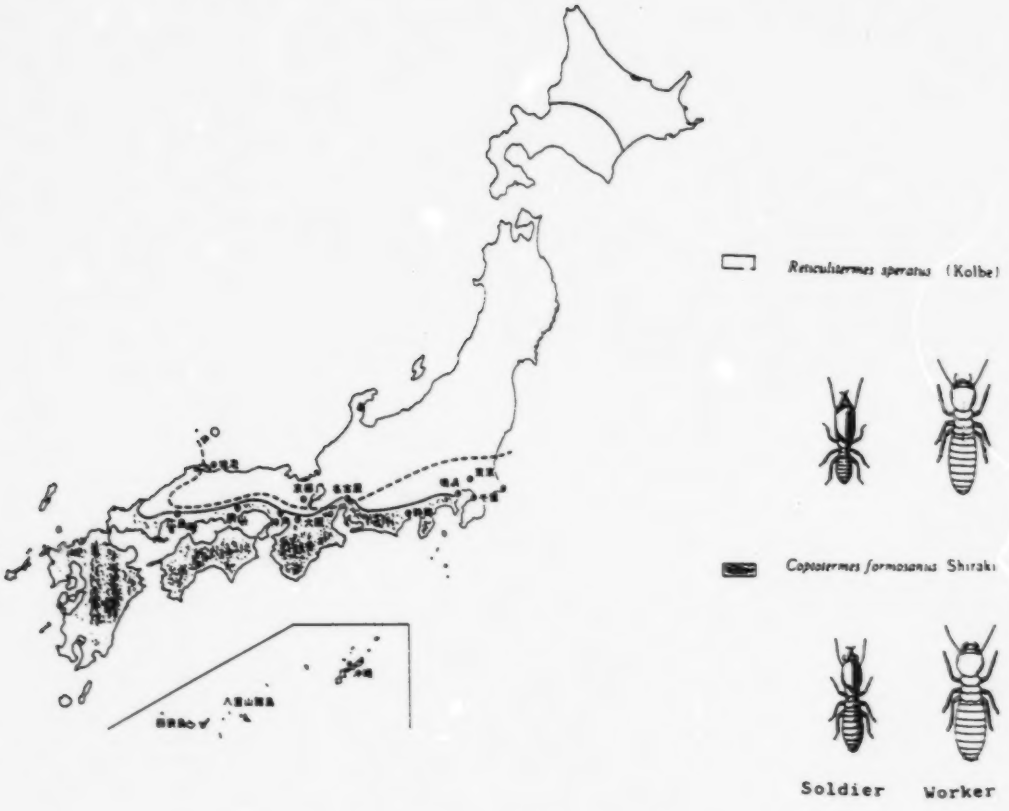


Figure 1 Termite distribution in Japan.

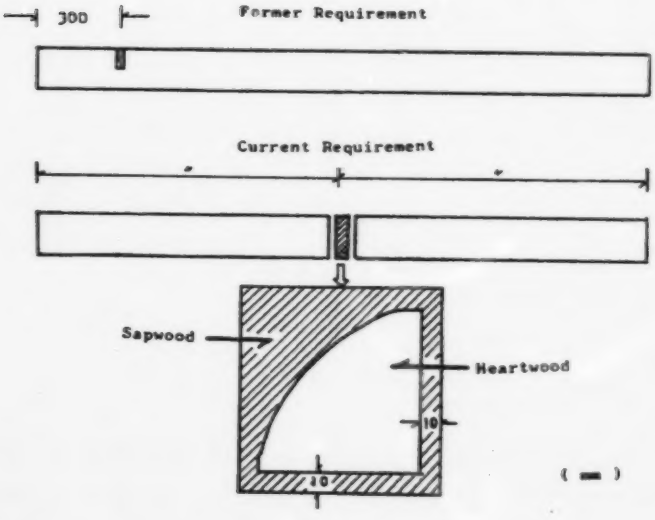


Figure 2 Sampling and penetration requirements of the former and current JAS standard.

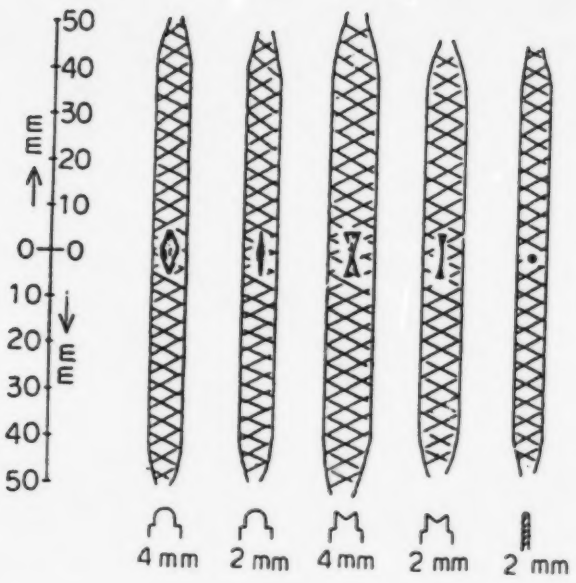


Figure 3 Preservative penetration pattern achieved in western hemlock with various incising teeth.

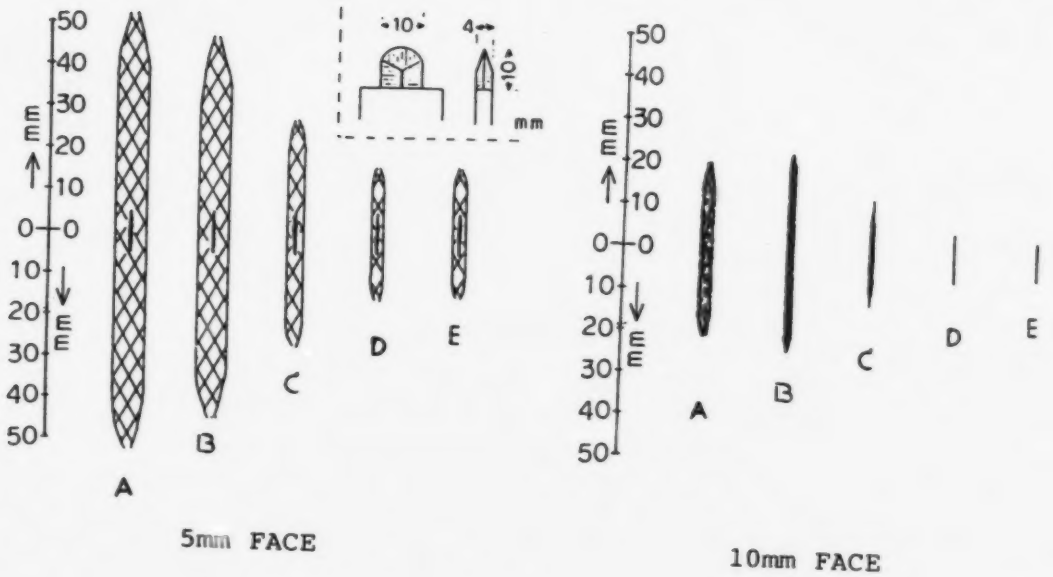


Figure 4 Penetration achieved in five wood species.

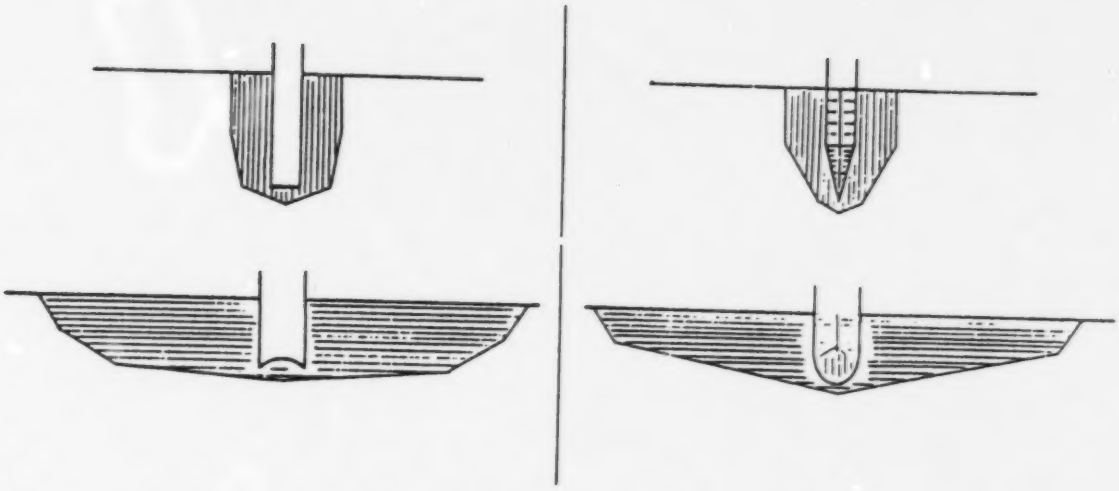


Figure 5 Influence of tooth profile on preservative penetration.

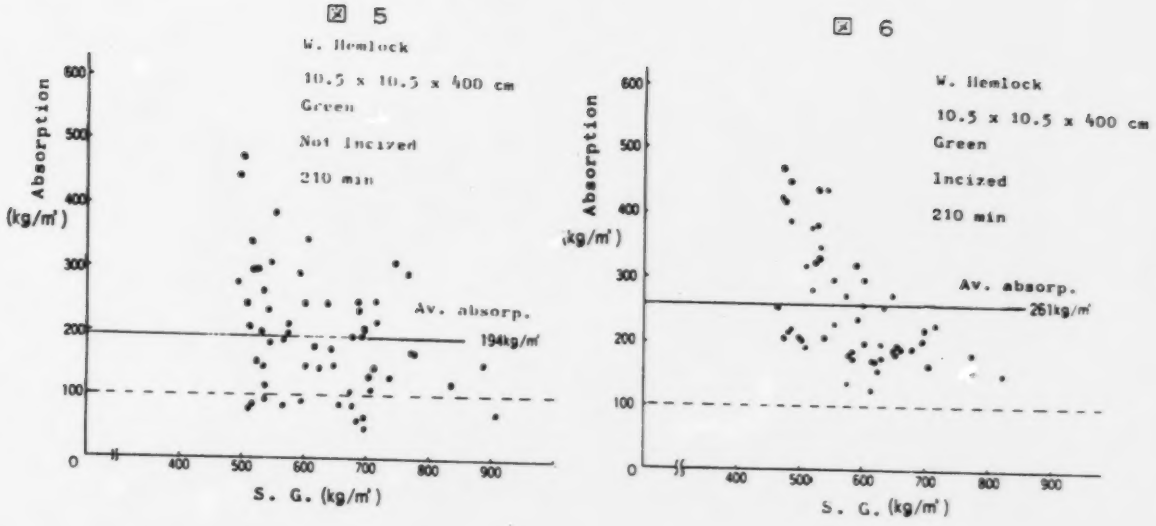


Figure 6 Distribution of net absorption (kg/m³) of green incised and non-incised western hemlock.

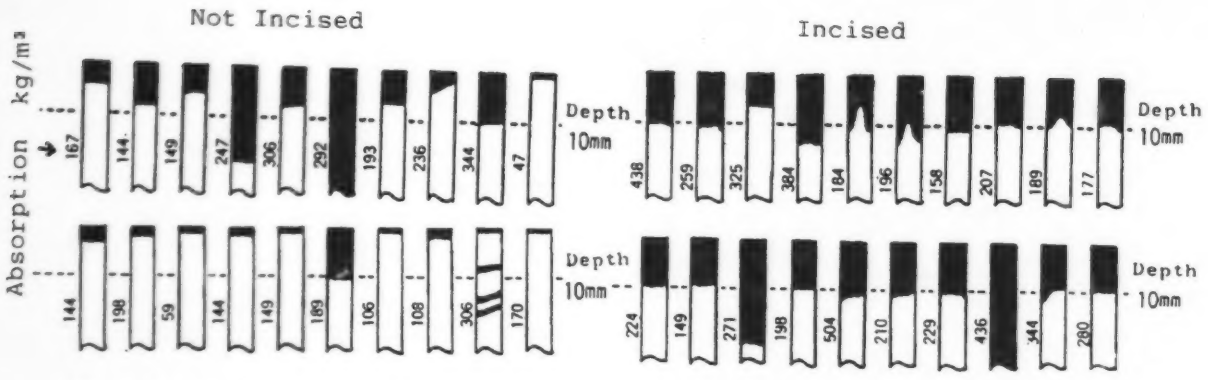


Figure 7 Penetration in borings removed from incised and unincised western hemlock timbers.

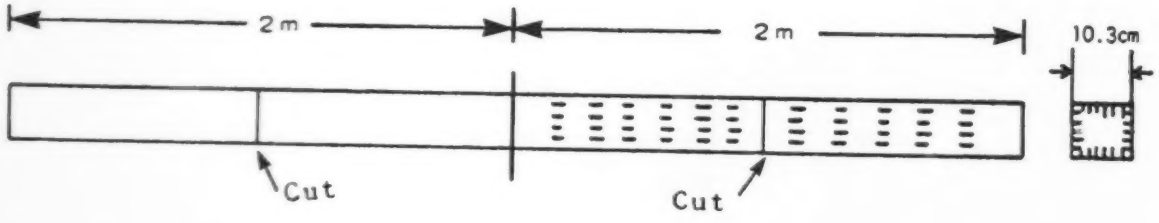


Figure 8 Incising pattern and sample sizes for investigation of western hemlock timber.

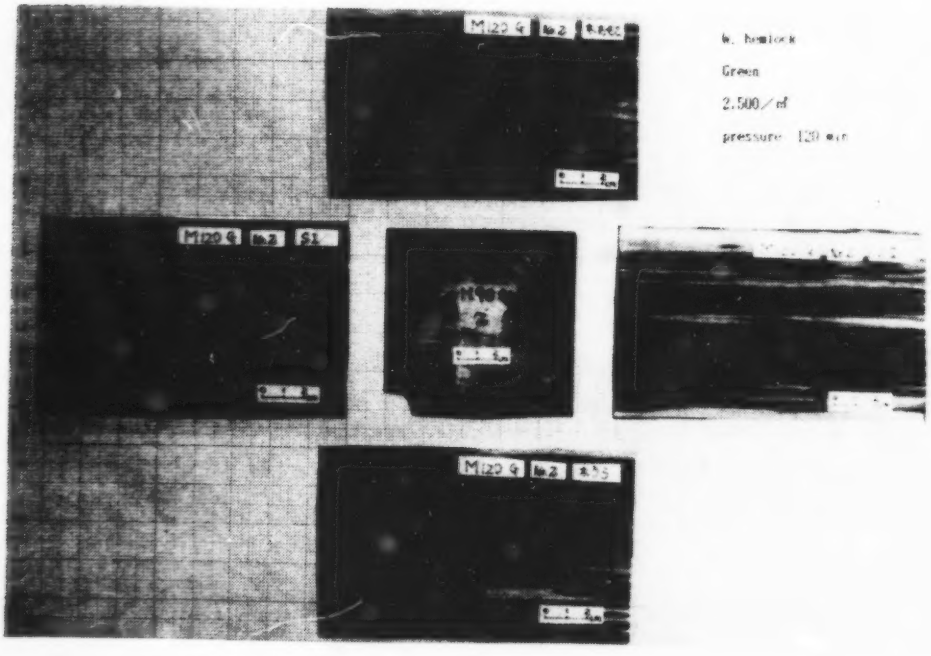


Figure 9 Penetration achieved in pressure treated (120 minutes) western hemlock.

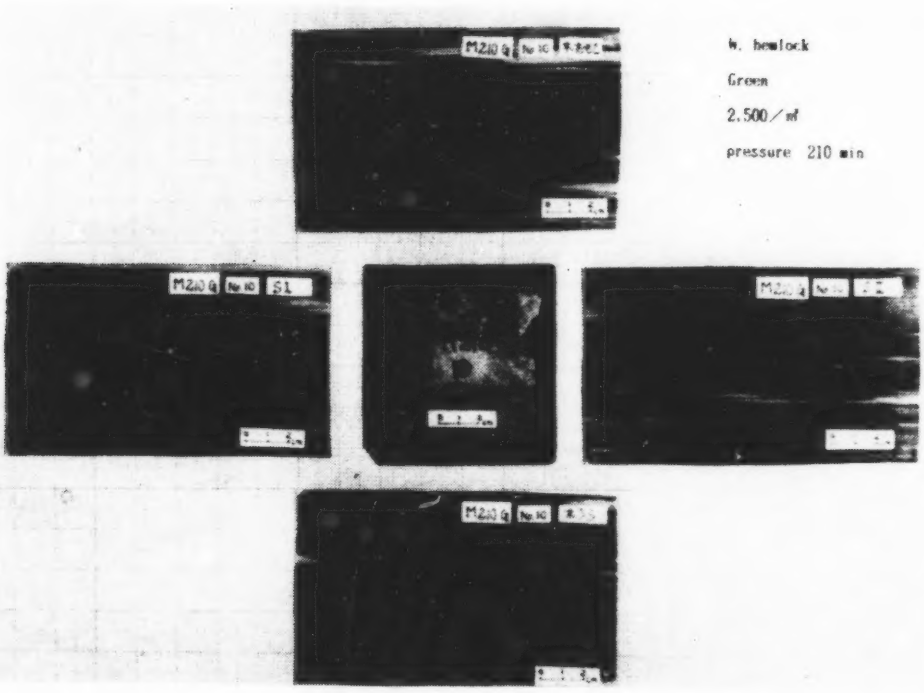


Figure 10 Penetration achieved in pressure treated (210 minutes) western hemlock.

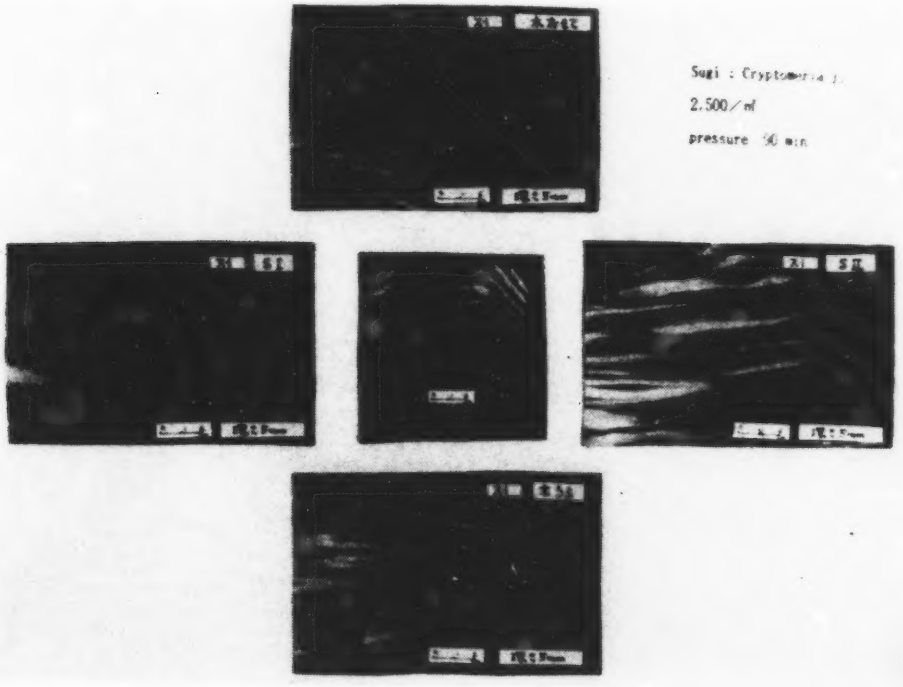


Figure 11 Penetration achieved in pressure treated (90 minutes) Sugi.

Figure 12 Penetration achieved in pressure treated Hinoki.

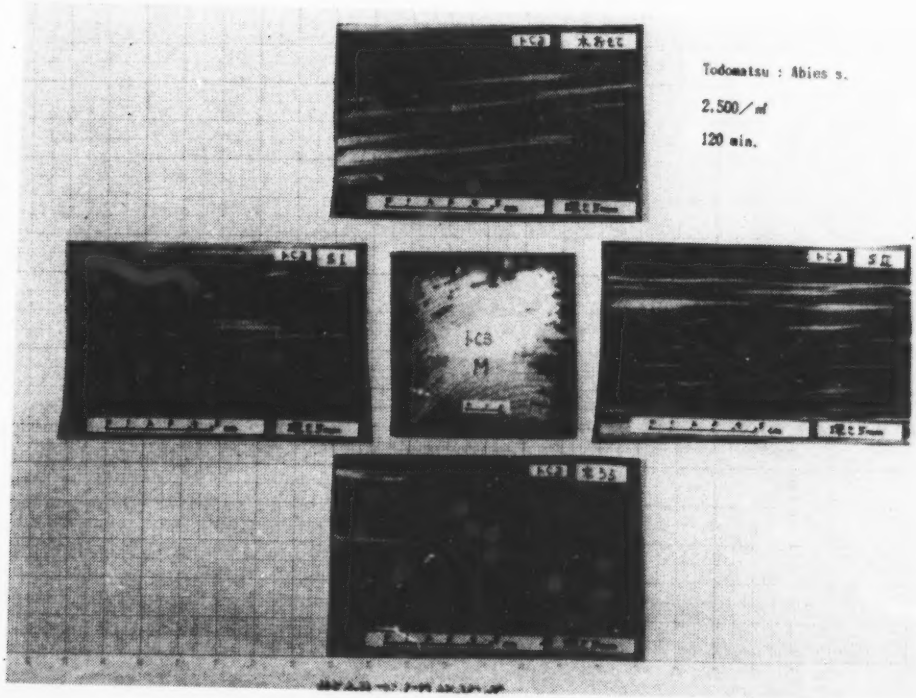


Figure 13 Penetration achieved in pressure treated Todomatsu.

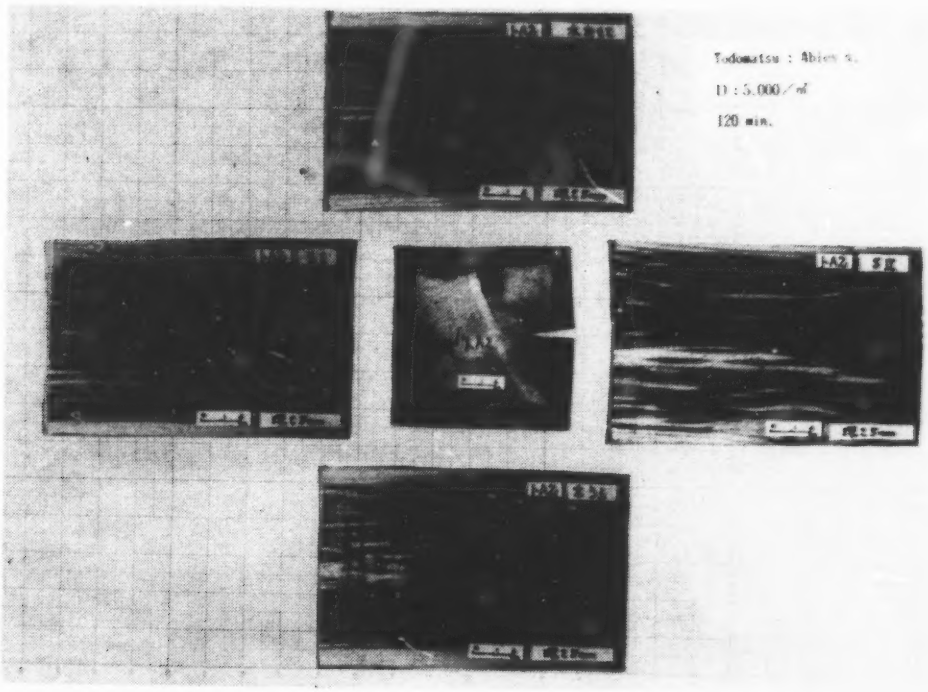
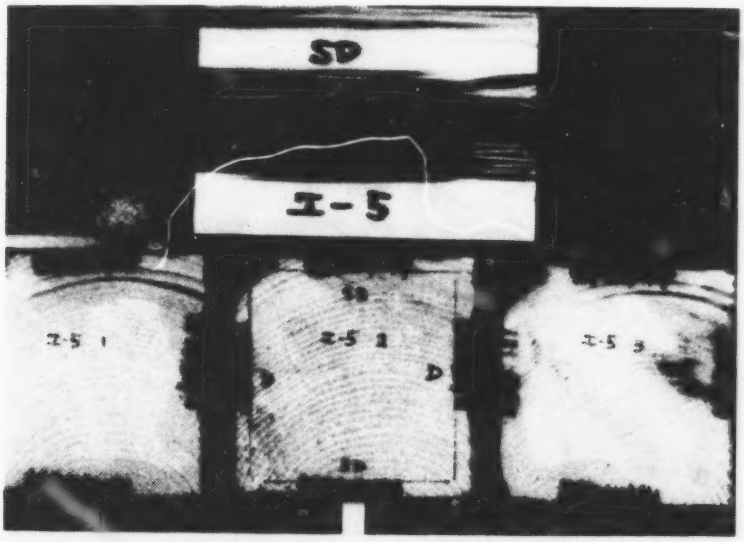


Figure 14 Penetration achieved in pressure treated Todomatsu incised with the denser incising pattern.



Ezomatsu : Picea j. 120 min.

D : 5,000／㎡ SD : 9,000／㎡

Figure 15 Penetration achieved in pressure treated Ezomatsu.

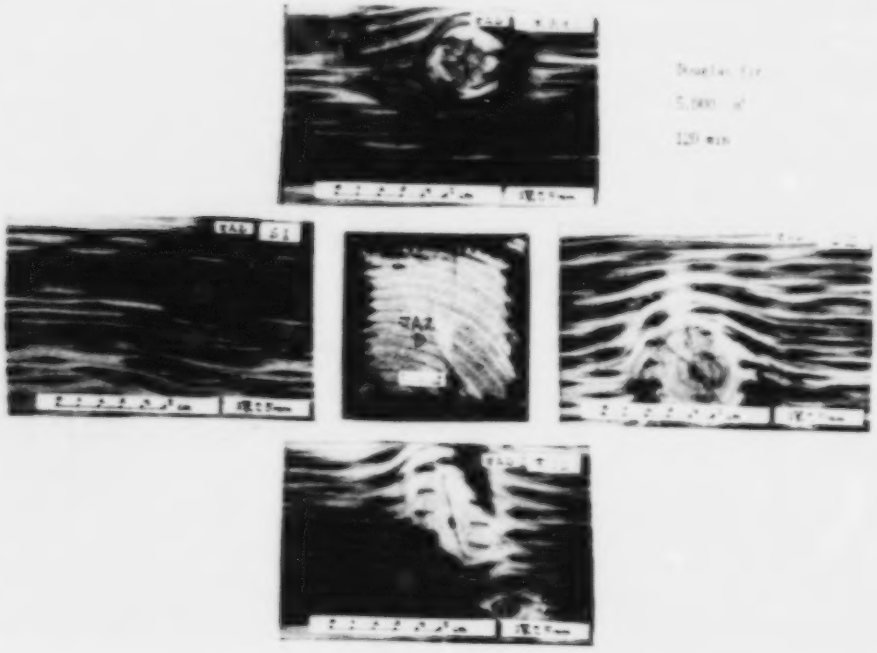


Figure 16 Penetration achieved in pressure treated Douglas-fir.

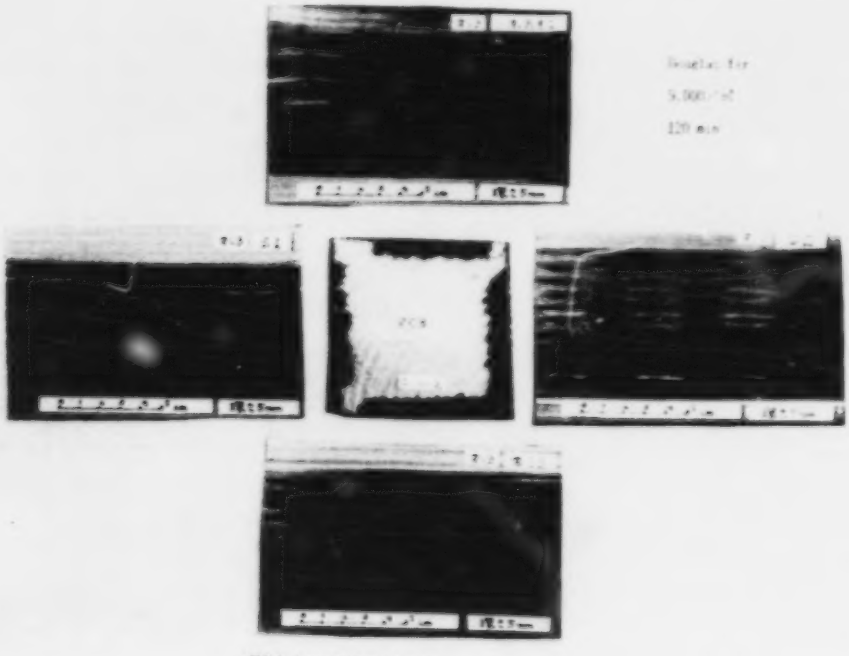


Figure 17 Penetration achieved in Douglas-fir incised with the denser incising pattern.

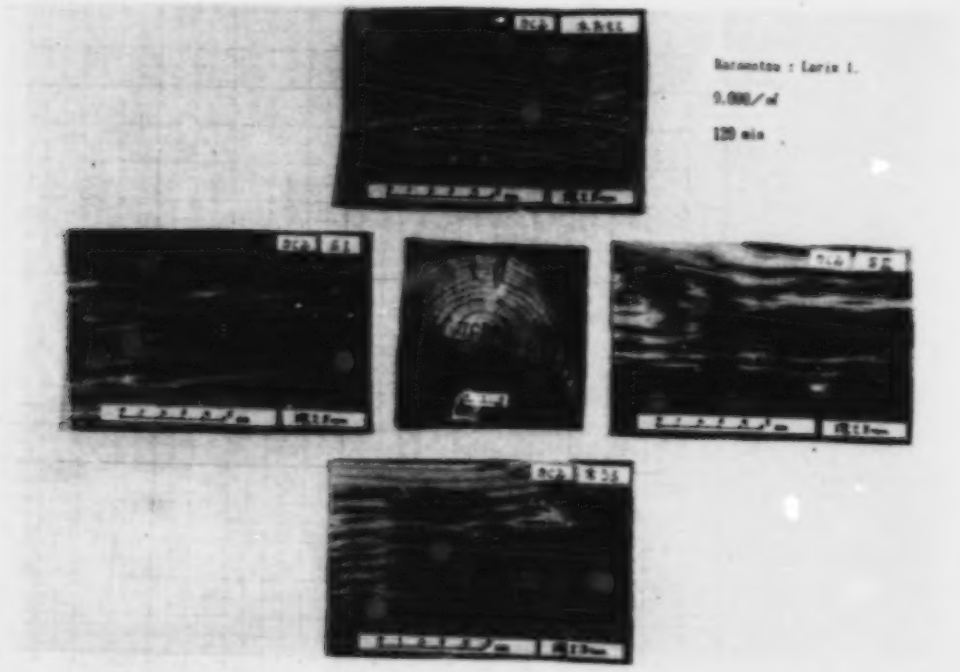


Figure 18 Penetration achieved in pressure treated Karamatsu.

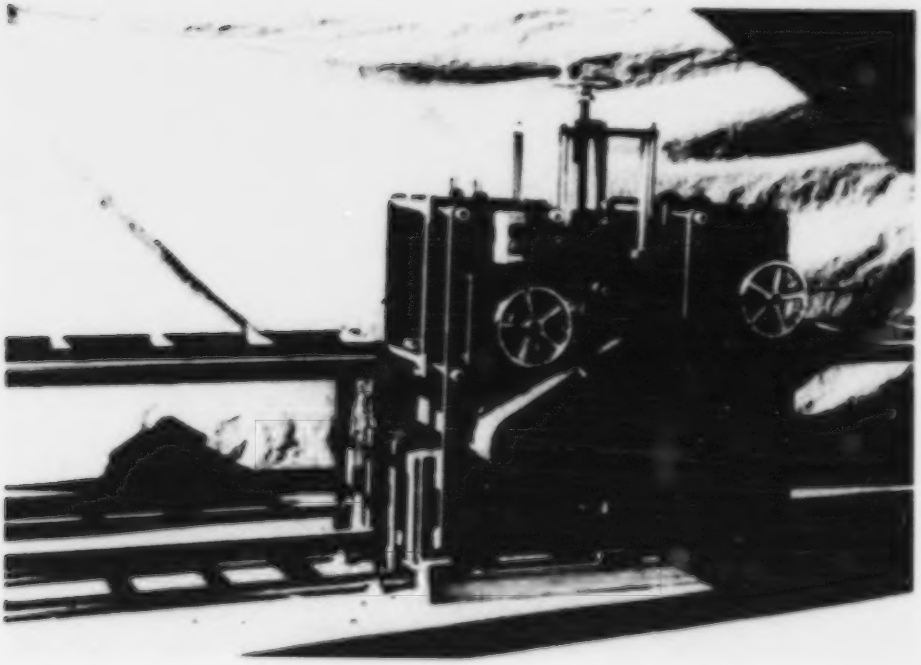


Figure 19 Koshii Preserving Co. Ltd. incisor.

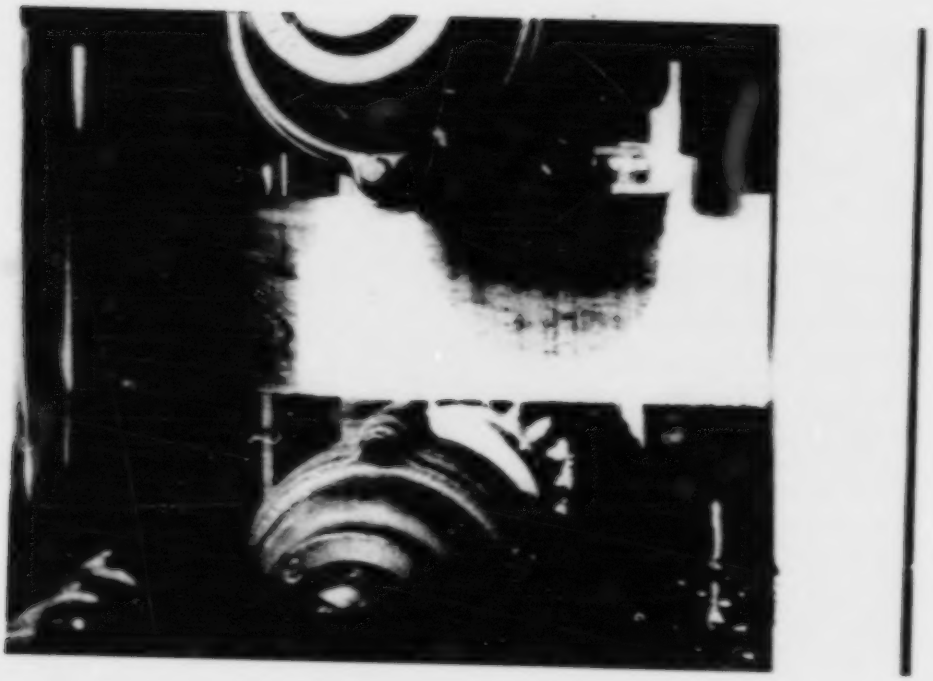


Figure 20 Koshii Preserving Co. Ltd. incisor.

Figure 21 Incisions produced by Koshii Preserving Co. Ltd. incisor.

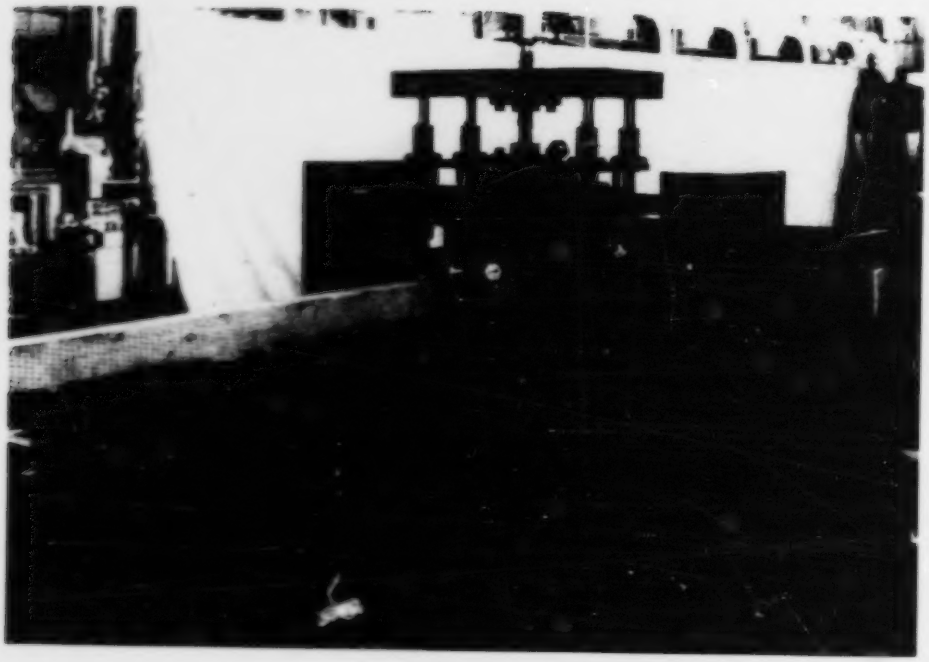


Figure 22 Fugi Kogyo Co. Ltd. incisor.

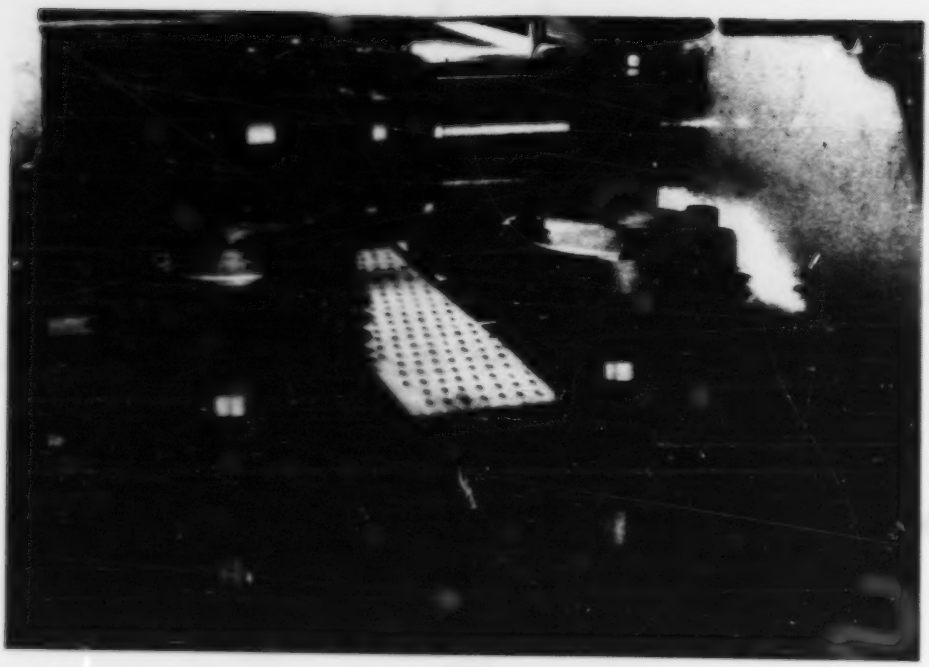


Figure 23 Fugi Kogyo Co. Ltd. incisor.

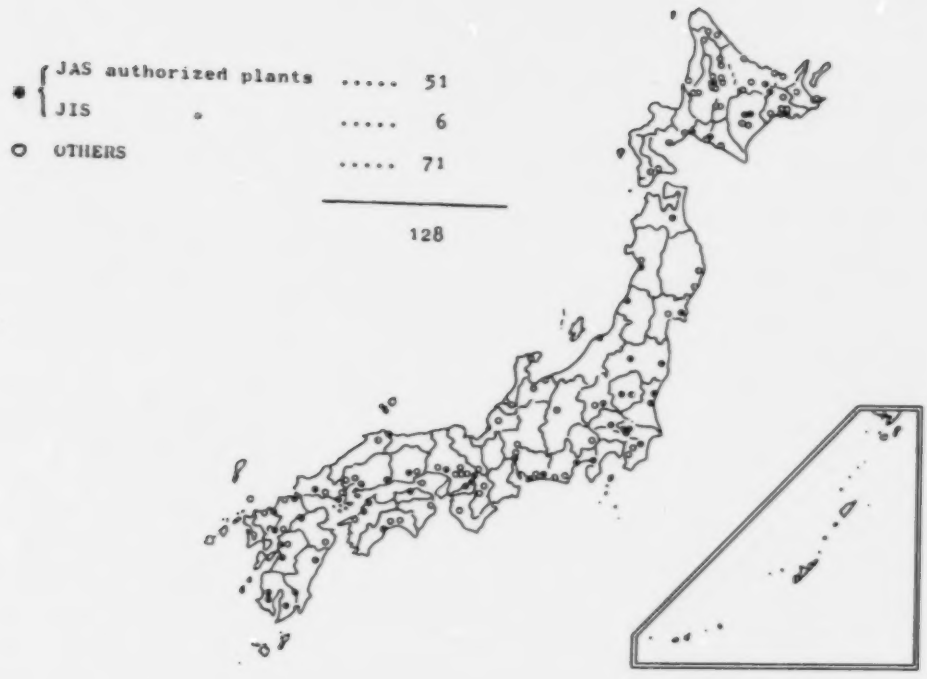


Figure 24 Distribution of CCA pressure plants in Japan.

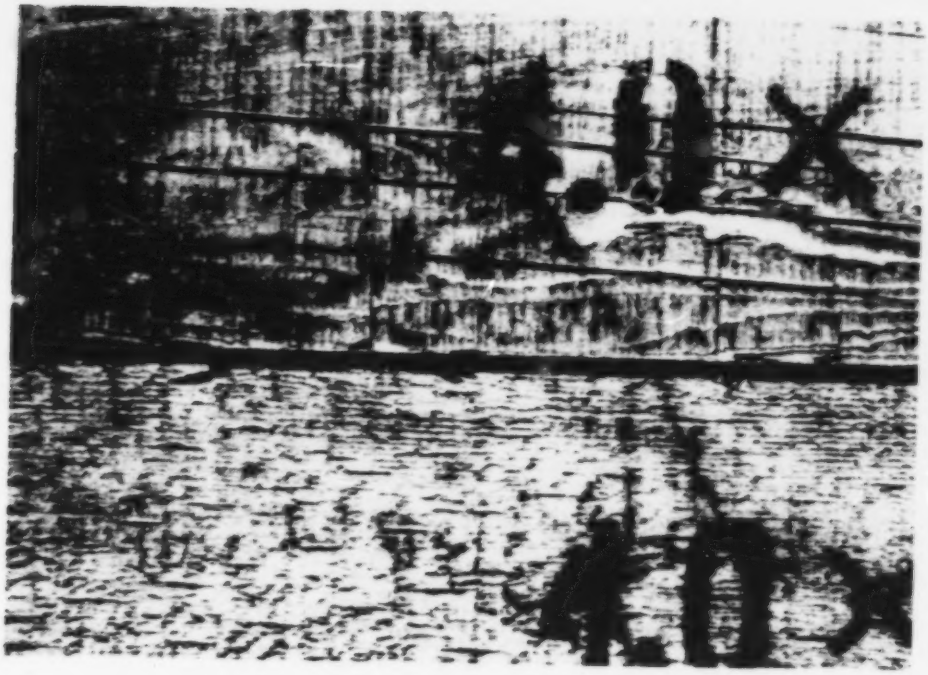


Figure 25 Reduction of large check formation in timbers, by incising.

MECHANICAL INCISING IN SWITZERLAND/GERMANY

by Francois W. Kropf
Swiss Federal Laboratories for Materials Testing and Research (EMPA)
Switzerland

Due to the economic aspects, any advanced incising technique developed for sawnwood is bound to be limited to special applications. We are quite sure that for a long time to come the "work-horse" for incising lumber and timber will be the mechanical incising systems. Wherever appearance or greater depth of penetration are not decisive the roller systems are much faster and will remain substantially cheaper in investment and operation. That is why, in parallel to our advanced work with laser incising, we have also continued to work on mechanical incising.

In 1980, our first step was to start with the incising process as it is still being practised in Germany today by the housing factories. Disks and tooth shape were from the Schiele Company. The pattern was very similar to that used in North America. The incision depth was 3 to 6 mm and loss of strength was irrelevant as the main purpose of the process was to meet the preservative retentions prescribed by the building codes (Figures 1, 2a, and 2b).

We then combined this process with the improved perforation pattern developed by the Western European Institute of Wood Preservation (WEI) (Figure 3) and tried to increase the depth. Starting from the concept developed by Desowag-Bayer, that for good preservative penetration you must open end-grain wood, the teeth of our disks were blunt and punched holes into the wood surface (Figure 4a). Accordingly, the combined force required to reach a depth of 10 mm for every tooth was very high and was overtaxing the machine. It was redesigned to accommodate the stresses, and with knot free wood it then worked quite satisfactorily. But this is not the kind of wood which is being used in the field to make glulams.

In a next step the disks were sharpened and a parallel penetration test of blunt versus knife-edged teeth was run (Figure 4b). A visual evaluation of penetration depth after pressure treatment produced the conclusion that preservative penetrations for both tooth shapes were roughly equivalent. It is therefore of interest that a rigorous investigation of this aspect by Bill Dost in Berkeley, as well as C.T. Keith of Forintek in Ottawa, has shown differences and we may have to look into the matter again. But measuring the pressures exerted in the bearings of the roller drum has demonstrated very clearly the great advantage of the sharp teeth. Over large knots the forces are being cut by a factor of 2 and more.

By then laser tests had shown that the length of the incision along the grain does not contribute to any extent to the lateral penetration, but has a significant influence on the loss of strength. Of even greater importance for glulam manufacturing, long incisions increase greatly the consumption of glue, as much of the glue applied gets lost into the many holes. In some instances the quantity of glue had to be doubled to obtain satisfactory glue-lines and this was not economically acceptable for the industry.

Therefore, the next step consisted in cutting down the length of the teeth from 10 mm to about 6 mm (Figure 5). But this was too drastic a reduction as the teeth started to break off. This would not have been dramatic as long as the wood surface did not require any further machining. But for glulam manufacturing a planing step after pressure treatment and drying is — at least in our opinion — absolutely necessary and one cannot take a chance on having a steel tooth stuck in the wood.

This last test-run showed us that quite frequently the tooth gets deflected by late-wood zones and as soon as it is slightly off center, the deflection increases with every new penetration until the tooth breaks off. Some of these problems could probably be solved by higher quality steel, but for this assistance is needed from the machine manufacturers.

Currently, as a temporary solution two of the disks are welded together and some preliminary tests have recently been conducted with disks of double thickness but short tooth-length. Of course the holes are quite unsightly after incising, but the swelling during pressure treatment with waterborne preservatives makes them close up to a large extent.

Incidentally it is on the basis of these last observations that the Schiele Company has lately developed a new incising device for round wood, which places the incisions across the grain (Figure 6).

This is the current status of our research at EMPA, but the investigation continues, as we are sure the mechanical perforation still has quite a potential for further optimization.

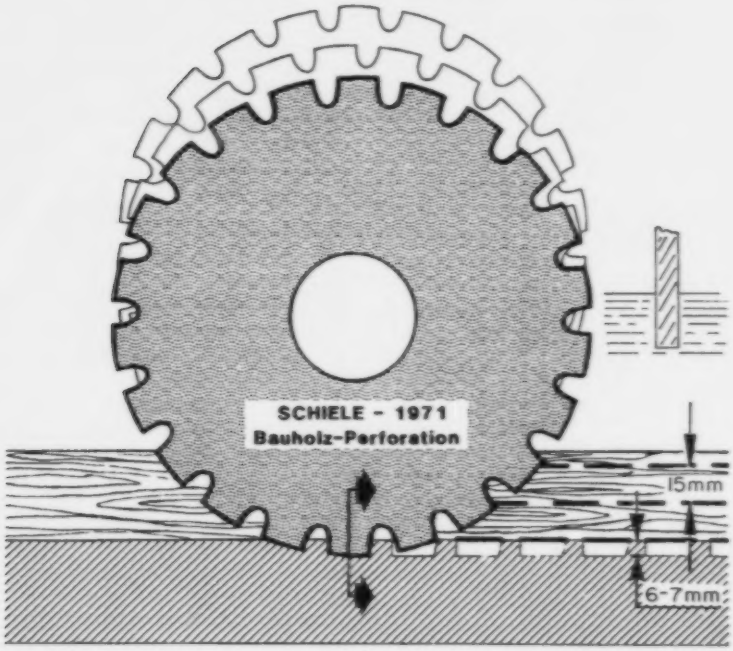


Figure 1 An early Schiele incising pattern created by blunt teeth.

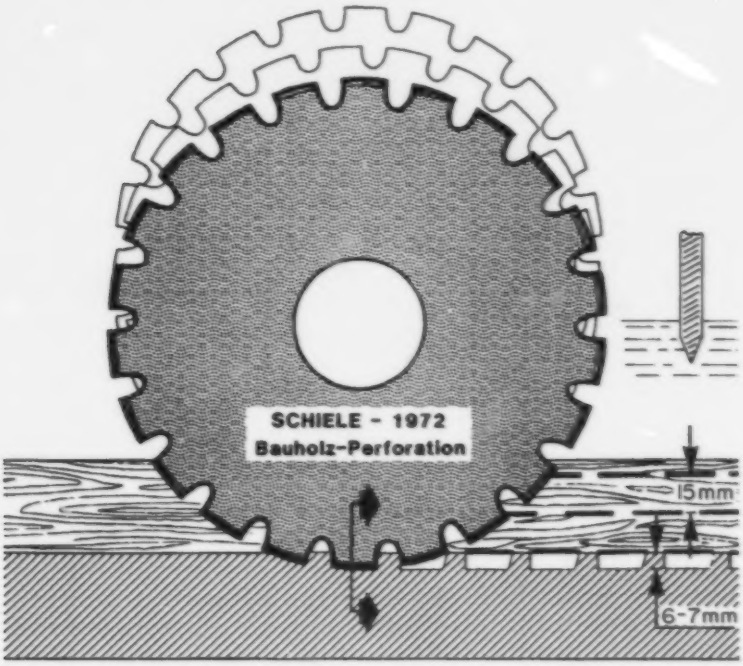


Figure 2a An early Schiele incising pattern created by sharpened teeth.

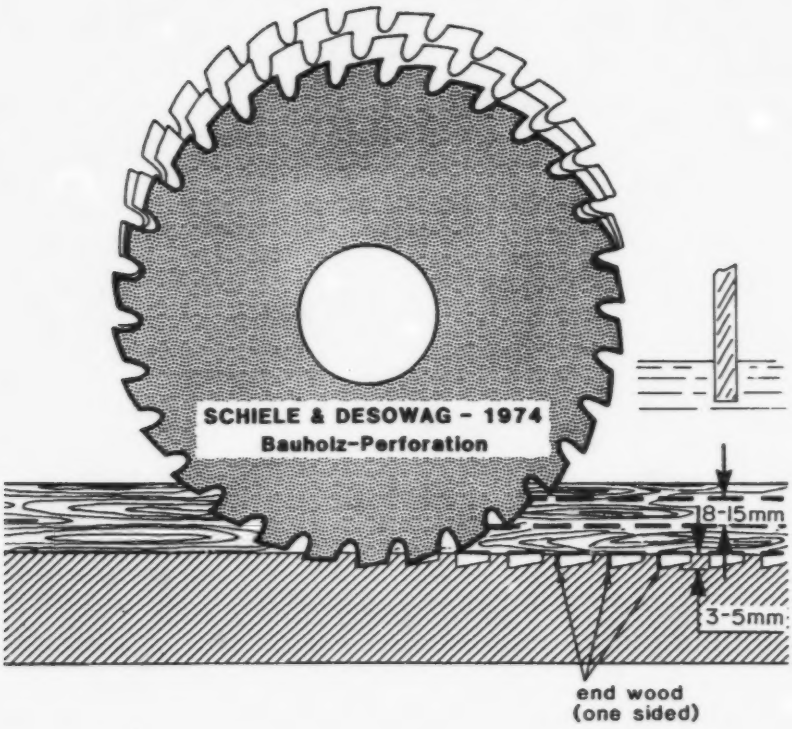


Figure 2b Early pattern developed by Schiele and Desowag-Bayer using shaped, blunt teeth.

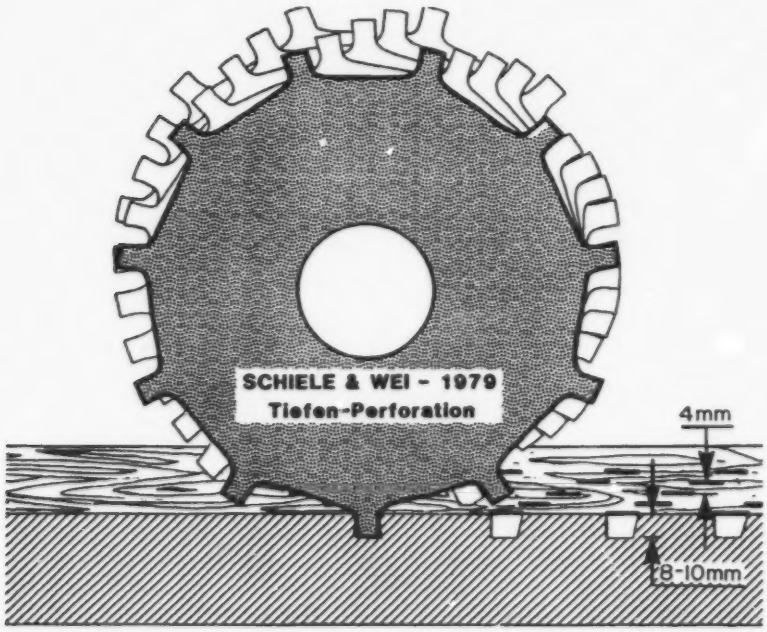


Figure 3 Combination of the Schiele incisor and the Western European Institute incising pattern.

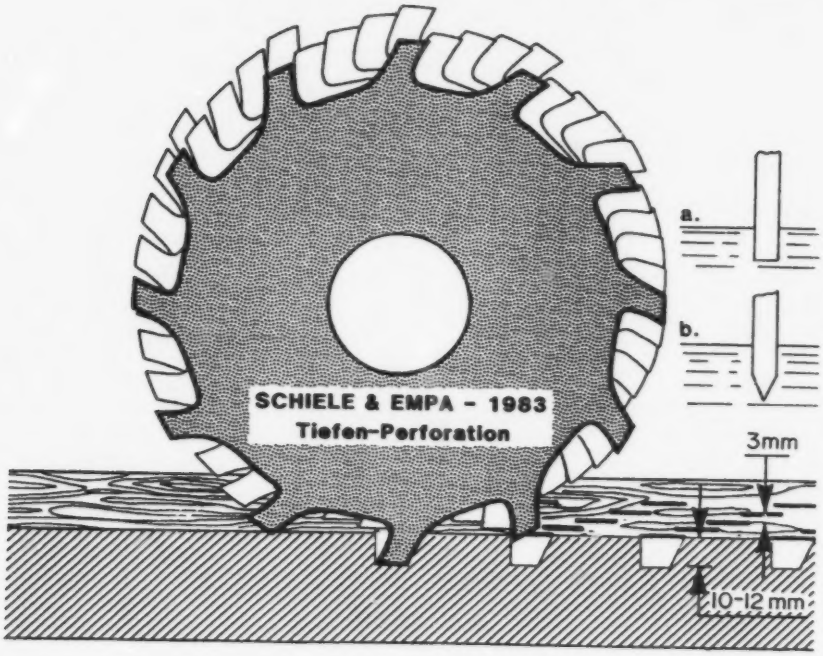


Figure 4 The EMPA modified Schiele incisor using blunt (a) and knife-edged (b) teeth.

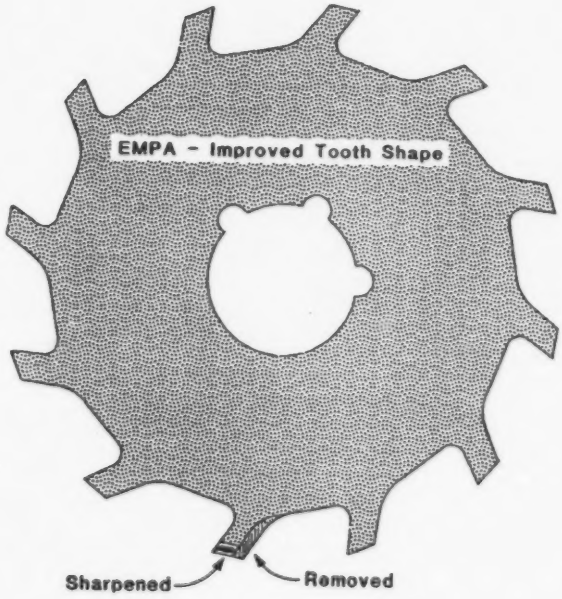


Figure 5 Modified incisor disc showing the reduction of the tooth length to 6 mm.

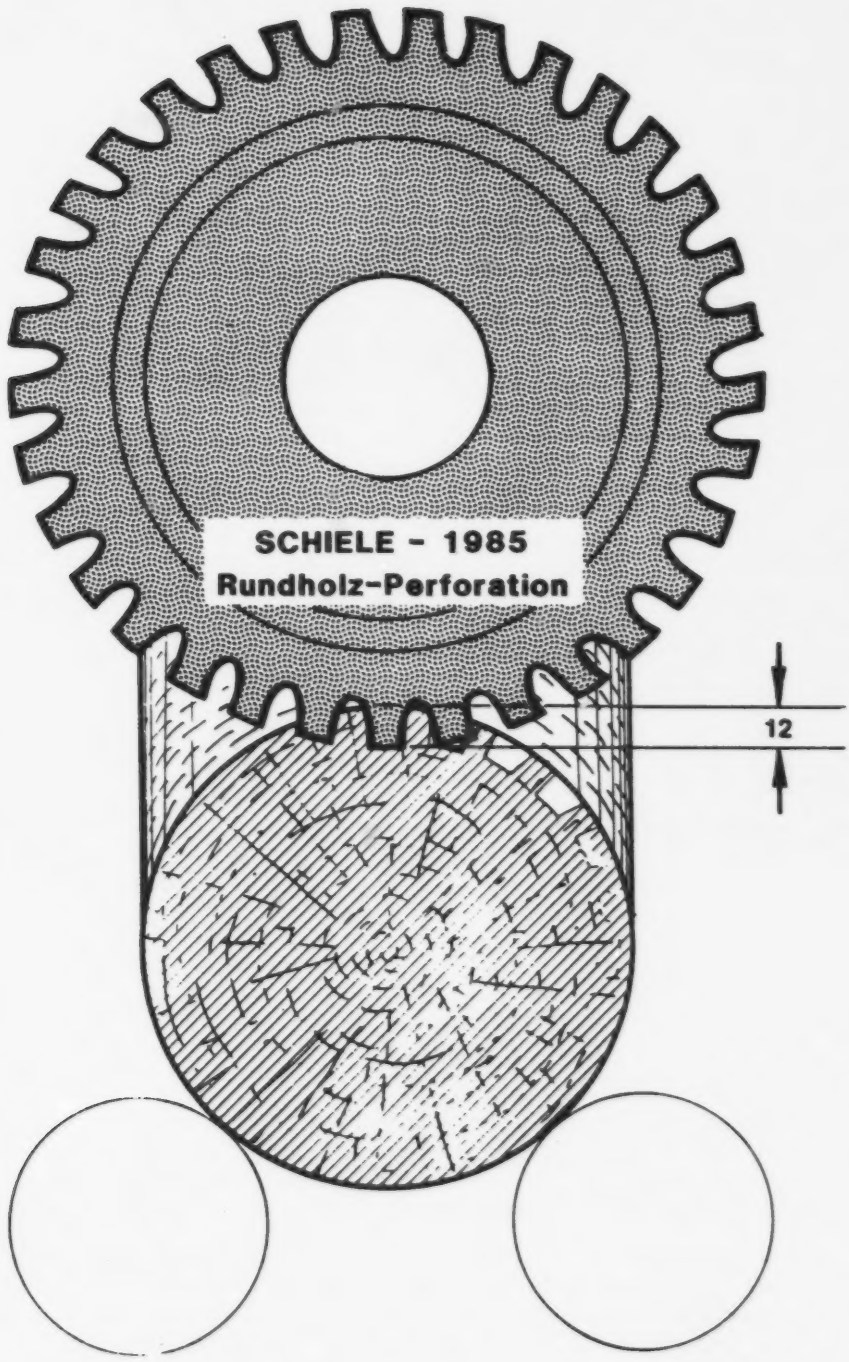


Figure 6 Recent innovations developed by Schiele for incising across the grain for round wood. Disc diameter is 180 mm.

MECHANICAL INCISING AND THE CLEAN-RING CONCEPT

by Ron Silcox
President
B.C. Clean Wood Preservers Ltd.
Surrey, B.C.

Today we have learned about new and novel techniques that could possibly lead to vastly improved methods of incising lumber, however, even though these developments are exciting, it is my personal opinion that conventional roller incising will be the mainstay for many years to come.

I wish to touch on some improvements available for incising machines, however, more importantly I wish to address the components that actually perform the incising process, namely, the teeth. I hope to point out the most common problems that have plagued the industry for many years and as well, offer solutions to these problems.

Firstly, let's deal with these problems from a practical perspective.

PROBLEM #1 - WIDELY SPACED PATTERNS

Twenty years ago, B.C. Clean Wood built their first incisor; at that time the teeth were spaced approximately 38 cm from each other. This spacing seemed to be the acceptable pattern within the industry and while the treating standards specified incising as a requirement, there was in fact no specified standard for incising itself. Another very distinct reason for this widely spaced pattern was to prevent or minimize the plugging of incisor rolls. I describe widely spaced patterns as a problem simply because the incising was inadequate with regard to improved wood preservation.

PROBLEM #2

Over the past ten years, research determined that closer incising patterns were required in order to achieve link-up of preservative bands from incision to incision. Because there was still no written standard on incising, the industry was confused as to what the ideal spacing should be, subject to species being treated. The end result being tooth spacing as high as 25 mm apart and as low as 3 mm apart. For those using closer spacings, it did not take long to revert back to a much larger spacing due to the plugging problems that were experienced. Those who did not increase the spacing inadvertently created the next problem.

PROBLEM #3 - DIMPLE INCISING

This very simply is the result of incising teeth being pushed into the lumber to a depth of only 1.6 to 3.2 mm. This occurs for two reasons: (a) the operator did not want to continually clean out lumber debris from the incising teeth, or (b) the incising teeth were already plugged to a point that no amount of pressure would see the incisors go past a depth of 3 mm.

PROBLEM #4

Some treaters had become frustrated with the lack of technology available for incising machines and the inability to achieve desired incision depths because of the plugging problem, therefore they have ceased to incise, period. This has created inadequately treated products in the marketplace especially in the area of commercial uses.

The most common denominator in the foregoing problems would seem to be the plugging of lumber debris between the incising teeth.

If this plugging problem were minimized, or eliminated the industry could:

- revert back to close incising patterns;
- eliminate down time that is normally required to clean heads;
- incise deeper and improve wood preservation practices;
- eliminate dimple incising;
- increase incising speeds; and
- create an incising standard.

B.C. Clean Wood has been involved in incising research for five years and quite frankly; we have had one simple motto, "TO IMPROVE UPON THAT WHICH IS PRESENTLY BEING PRODUCED IN THE MARKETPLACE". Obviously our research does not carry the authoritative impact that one comes to expect from research companies such as Forintek Canada Corp., however, we do have the advantage of a practical approach under actual operating conditions.

One of the successes we wish to report on today, is a system known as the "Clean Ring Concept". This "Patent Applied For" process will be available to the treating industry throughout North America effective January 1987. While the concept is simple in nature, it has nonetheless seen extensive testing throughout 1986 by way of processing in excess of 50 million BM.

As a treater:

- we have achieved a close incising pattern where the teeth never plug with debris;
- we have eliminated all down time with regard to cleaning;
- subject to operator competence, we have eliminated dimple incising;
- we have tripled the speed of our incisor; and
- we sincerely want to see the creation of an incising standard.

The Clean Ring System is based on the concept of providing a cleaning apparatus for each tooth ring in use. The system may be incorporated on any size or style incisor with the exception that the incising teeth must be a "ring" configuration. Incisors can now have many options, for example dimensional spacing, whereby at the common sizes for lumber, teeth are eliminated in order to prevent edge damage to select, structural products. A treater may also use any configuration of tooth design, be it blunt or sharp. There may be any number of teeth on a ring and one may choose between an inline or offset diamond pattern.

There remains, however, one word of caution that should be made; there will come a point in the use of a close spaced incising pattern where lumber fragments will always be stripped away, due to having incising teeth too close together. This could result in an unsaleable product.

At this point I would like to show some slides that will better demonstrate not only the Clean Ring Concept but, also, various improvements that should be considered during incisor design.

Earlier I referred to the widely spaced patterns as being a problem because they do not permit adequate integrity of penetration. At a depth of 8 mm there was very definitely no link-up of the preservative bands in the wood. However, we noted that in some samples where incisions happened to be closer spaced, better penetration resulted and that if a better pattern was incorporated, link-up could have been achieved. This convinced us that prior to adopting a closer incising pattern we must determine which would be better, offset or an inline type of spacing.

We decided to test the "very difficult to treat" species, Douglas-fir. The inline pattern clearly produced a poor treatment. Conversely the offset diamond pattern produced far better results. This convinced us that the pattern to use was the offset. However we went one step further and participated in a nationally organized study. Lodgepole pine, jack pine, red pine and hemlock from various regions in Canada were used, and the test consisted of matched samples using the same two incising machines in all cases. The significance of this test was to compare the difference between an ultra close inline pattern to that of an offset pattern which contained 25% less incisions. The result showed there was no significant difference in penetration results. We were convinced and therefore converted to a close offset diamond pattern.

This created a big problem — up to 1.5 hours per shift were spent cleaning incisor heads. Poor incision depths produced poor treating. The poor performance despite an adequate incising pattern was most frustrating for both management and the employees. Sometimes, immediately after cleaning, the first board put through would plug up the teeth. Obviously, because volume production is essential there were times we would continue incising with a plugged head resulting in dimple incising.

Eighteen months ago, the problem was solved by the creation of the "Clean Ring Concept". Each Clean Ring floats between the tooth rings and uses the lumber itself as the driving force. On some models there are no dimensional spacer rings because they process primarily large, rough timbers. As well, there are two "idler rollers" that serve to keep the Clean Rings in their fully extended position. This prevents the cleaning ring from becoming wedged or bent over if the timber wanders off the lumber line slightly. With the introduction of this system the small piles of lumber debris that collect under the incisor during operation are a constant reminder that these pieces would have been wrapped around the incisor head if it were not for the cleaning system.

Another of our developments created three years ago, is the "Dial-A-Depth" system. An operator can now dial the exact pressure it takes to push the incising teeth into the dimension of lumber being processed. Obviously it takes less pressure to incise 5 x 10 cm lumber compared to the larger 5 x 30 cm boards. The smaller hydraulic cylinder on top maintains the preset pressure, regardless of any changes in lumber size that may occur during the processing of lumber. If a 15 x 15 cm timber entered the incisor measuring 14.6 x 14.6 cm and upon exit is measured at 15.9 x 15.9 cm these smaller cylinders would allow for the size change and all the time maintain the exact preset pressure that is required to sink the teeth. One can imagine the condition of the 15 x 15 cm timber at the larger end if processed on an incisor that did not provide this type of variance. There is one other way to handle this problem and that is to set your incisor to the size of the large end, however, you would end up dimple incising the smaller end.

Now, with the combination of Dial-A-Depth and the Clean Ring Concept, processing speeds of up to 152 linear m/minute can be achieved. For these slower speeds and larger dimensions, one needs to be able to control torque. Obviously it takes a lot more power to incise a 15

x 15 cm than a 5 x 10 cm board. An incisor running at high speed is somewhat like a planer. One should have the ability to make precise adjustments — in this case, the fine adjustment of the side heads in relation to the lumber line and the top and bottom heads.

The use of "Dimensional Spacers" allows the edge of the lumber to ride in the exact centre of a thicker cleaning ring. Dimensional Spacer Rings can be placed to match the common sizes processed by a treating plant; for example, the difference between green and dry sizes. Because there is a Dimensional Spacer for each common size, 5 x 10 to 5 x 30, small 1.0 cm bands of unincised areas will occur when larger widths are processed. We do not believe that this creates a severe penetration problem, especially when one considers the advantages of having clean, undamaged edges.

The previously described features or concepts will now allow the use of thinner and more delicate incising teeth. The end result is a superior piece of treated wood that is also acceptable aesthetically. This can be of great advantage to Canada's industry considering the volume of wood used in Canada for sundecks and patio applications.

We still consider that our incised wood is not perfect, and have noted some cases where penetration is only slightly improved. However using the incising techniques described above treatment quality has increased by 92%.

THE PROBLEM! That is behind us now — the Clean Ring system has changed our daily frustrations to a very contented feeling when all we have to do is throw these pieces into a garbage box. The treating industry very clearly has a choice now, and it is only the industry that can guide the future and ensure continued market growth, through a quality product.

INCISING VENEER TO REDUCE DEGRADE IN DRYING AND IMPROVE PRESERVATIVE TREATABILITY

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SUMMARY

Laboratory experiments and two mill trials were conducted to evaluate the effect of incising veneer on warping (buckling), drying and preservative treatability. A roller incisor containing numerous chisel-shaped incising teeth was fabricated at the Western Laboratory of Forintek Canada Corp. Five degrees of incising ranging from light to heavy were evaluated. In the mill trials, the incising, especially the heavy degree of incising of unseasoned, 1.5 mm cottonwood veneer, showed definite improvements in both drying rate and warping during drying. The warping was reduced by approximately 12 percent as measured by height of veneer stacks. Laboratory experiments confirmed that there was an increase in initial drying rate for the incised 1.5 mm cottonwood veneer, with the heavy degree of incising showing the largest increase of 11.7 percent over the control. Laboratory experiments using X-ray analysis also showed that spruce plywood made from incised veneers (medium degree of incising) picked up 24 percent more by preservative (CCA-C) weight compared to the controls. More importantly, the preservative penetration was 50 percent greater in the inner plies of the incised spruce plywood.

1.0 INTRODUCTION

Forintek Canada Corp. has been developing an incising system which operates on our lathe. It was believed that such an incising system would reduce the extent of problems in plywood plants associated with buckling and splitting of veneer during drying. To evaluate the usefulness of Forintek's incisor, a machine was built that was capable of incising full-sized sheets in the direction of the grain. A plant glue spreader was modified and an incising roller was fabricated. This incising roller contained numerous chisel-shaped incising teeth. Controls on the machine enabled varying degrees of incising to be carried out.

Two mill trials were conducted to evaluate the effect of incising veneer on warping (buckling) and drying. Laboratory tests were also conducted to evaluate the effect of incising on rate of drying and preservative treatability.

2.0 EXPERIMENTAL

2.1 MILL TRIALS

For the first mill trial, 300 green, 0.9 x 2.4 m, 1.5 mm cottonwood veneer sheets were incised on an incising system built at the Western Laboratory, Forintek Canada Corp. Every second veneer sheet was used as a control, giving a total of 300 controls. A glue spreader was converted into an incising unit. A 1.37 m roller was constructed such that it contained hundreds of chisel-like teeth. By adjusting the controls on the incisor unit, four degrees of incising, ranging from light to medium, were used in the first trial. The incisor controls affected the amount of pressure applied to the veneers. All the veneers were weighed and labelled before being transported to the mill and run through the dryer. The dryer was set at 177°C and the veneer took 28 minutes to run through the dryer. After passing through the dryer, the veneer was brought back to the Western Laboratory, weighed and then further dried to oven dry weight in an experimental drying kiln. The veneers were weighed again. The average heights of the control and incised veneer stacks were measured. Green and oven dry moisture contents were calculated from the weight measurements.

For the second trial, 48 green, 0.9 x 2.4 m, 1.5 mm cottonwood veneer sheets were incised on the previously-described incising unit, using a heavy degree of incising. These heavy incisions went right through the veneer thickness, unlike the light and medium degrees of incising. Every second veneer sheet was used as a control, giving a total of 48 controls. The veneers were weighed and labelled before being transported to the mill and run through the dryer using conditions similar to those in Trial 1. The same procedure as Trial 1 was used to evaluate the dried veneers.

2.2 LABORATORY EXPERIMENTS

2.2.1 Rate of Drying

Samples of 30 x 30 cm and 30 x 76 cm dimensions were cut out from green, 1.5 mm cottonwood veneer. Half the samples were incised with the incising unit used in the mill trials, using a light, medium or heavy degree of incising. The other half of the non-incised samples were used as controls. The control sample for each degree of incising was selected such that it was adjacent to the sample used for incising from the same veneer sheet. For the drying rate experiments, a control and an incised veneer sample were placed in a preheated oven at 180°C. The oven had an air circulation speed of 152 m/min. At two-minute intervals, the veneer weights were recorded. The positions of the veneers were interchanged each time they were placed back in the oven to ensure similar drying conditions.

2.2.2 Preparation and Preservative Treatment of Incised Plywood Panels

Spruce veneer sheets (2.5 mm, 1.2 x 2.4 m) sheets were ripped into two pieces (2.5 x 2.5 m), one of which was used as a control while the other was incised on the laboratory incising unit using a medium degree of incising. The sheets were dried to an average moisture content (mc) of three percent and were made into seven-ply incised and non-incised panels using matching veneers. The seven-ply panels were made using standard plywood manufacturing procedures and phenol formaldehyde glue. Samples of 30 x 60 cm dimensions were cut from the seven-ply panels and edge-sealed. The samples were then pressure-treated with 2.3 percent chromated-copper-arsenate type C (CCA-C) solution. Weights before and after treatment were measured for each plywood panel. A 2.5 cm diameter core was removed from the center of each plywood panel and analyzed using an X-ray method to calculate total preservative uptake.

3.0 RESULTS AND DISCUSSION

3.1 MILL TRIALS

The results for the two mill trials are shown in Table 1. The average green moisture contents between each set of control and incised cottonwood veneers were very close, and identical in several cases. As an indicator of warping caused by drying, average heights of stacked dried veneer were measured. Lower heights were indicative of less warping. For all degrees of incising, the average heights were lower for the incised veneer compared to the control. Significant reductions in the degree of warping were observed with the medium and heavy degrees of incising. For the heavy degree of incising in Trial 2, warping was reduced by approximately 12 percent as measured by height of veneer stacks; 31 cm for the control stack compared to 27 cm for the incised veneer stack (Table 1).

Mill Trial No. 2, using heavy incising, showed the greatest effect on drying the 1.5 mm cottonwood veneer. The faster drying rate of the heavy incised veneers is reflected by the result that 15 percent of the control veneers were above five percent mc compared to zero percent above five percent mc for the incised veneers (Table 1). Because only two moisture contents were measured during the mill trials, it was not possible to quantify the effect of incising on drying rates. Therefore, the following laboratory studies were conducted to quantify drying rates for different degrees of incising.

3.2 LABORATORY EXPERIMENTS

Initial drying rates for control and incised veneers are shown in Table 2. Both the control and incised veneers were dried in a preheated oven set at 180°C. For each degree of incising, the initial drying rate for the incised veneer was faster than that for the control. The increases in drying rates over the controls were 8.7 percent for light incising, 5.4 percent for medium and 11.7 percent for heavy incising. Thus, the heavy incising produced the largest effect on drying rate. This was also observed in the mill trials.

The results of the laboratory experiments for non-incised and incised plywood panels treated with 2.3 percent CCA-C solution are shown in Tables 3, 4 and 5. Both the gravimetric (Table 3) and X-ray analyses (Table 4) showed that the incised panels picked up significantly more by weight of preservative compared to the controls. Thus, the gravimetric analysis showed that, on the average, the incised plywood panels picked up 17 percent more by weight of preservative compared to the controls, while the more accurate X-ray analysis showed that the incised plywood panels picked up 24 percent more by preservative weight.

The most significant finding was the much greater preservative penetration into the inner plies for the incised spruce plywood (Table 5). As expected, the average percent penetration was high for the face veneers of both the non-incised (96 percent) and incised (100 percent) plywood panels. However, there was a very large difference in average preservative penetration for the interior plies, 55 percent for the non-incised panels compared to 81 percent for the incised panels. This represents a 50 percent increase in penetration in the inner plies for the incised plywood compared to the control. Further, a much more uniform degree of penetration was observed in the incised plywood when compared to the control.

4.0 CONCLUSIONS AND RECOMMENDATIONS

In the mill trials, the incising, especially the heavy degree of incising of unseasoned, 1.5 mm cottonwood veneer, showed definite improvements in both drying rate and warping during drying. Laboratory experiments confirmed that there was an increase in initial drying rate for the incised 1.5 mm cottonwood veneer, with the heavy degree of incising showing the largest increase of 11.7 percent over the control. Laboratory experiments using X-ray analysis also showed that incised spruce plywood (medium degree of incising) picked up 24 percent more by preservative (CCA-C) weight compared to the controls. More importantly, the preservative penetration was 50 percent greater in the inner plies of the incised spruce plywood. It is recommended that further studies be conducted on incising veneer in which new incising rollers be fabricated capable of producing heavy degrees of incising.

Table 1

Moisture Data for Two Mill Trials

Mill Trials	No. of Test Veneers	Controls or Degree of Incised Veneers	Avg. Green m.c.	Range of Green m.c. (percent)	Avg. Dry m.c. (percent)	No. Veneer Sheets Re-Dry (Mill Sensor)	No. Veneers Over 5% m.c.	Avg. Height of Stacked Veneers (cm)
No. 1	75	Control	164	84 - 247	3.7	25	20	50.3
	75	Light incised	161	75 - 223	3.6	27	21	48.3
	75	Control	145	48 - 231	3.5	12	14	48.7
	75	Light incised	146	60 - 243	3.3	10	19	48.3
	75	Control	161	102 - 238	1.8	2	7	42.4
	75	Medium incised	161	115 - 240	2.6	5	12	41.1
	75	Control incised	173	113 - 248	2.6	15	10	39.6
	75	Medium incised	173	108 - 273	2.5	10	8	35.8
No. 2	48	Control	141	111 - 174	2.9	0	7	31.0
	48	Heavy incised	139	101 - 174	1.1	0	0	27.1

Table 2

Initial Drying Rates for Incised 1.5 mm Cottonwood Veneer Heated at 180°C

Light Incising		Medium Incising		Heavy Incising	
Control	Incised	Control	Incised	Control	Incised
(g/min.)		(g/min.)		(g/min.)	
9.8	10.0	13.6	13.7	16.7	19.4
13.9	14.3	16.0	16.4	34.6	39.0
14.0	15.4	16.5	17.6	14.7	15.7
26.9	30.3	27.9	30.4	16.3	17.8
Average					
16.1	17.5	18.5	19.5	20.6	23.0

Table 3

Preservative (CCA-C) Uptake Data for Incised and Control Spruce Plywood

	Weight Before (g)	Weight After (g)	Weight Uptake (g)	Weight Retention (kg/m^3)	Oxide Retention (kg/m^3)
1 A C*	1061.8	2460.0	1398.2	556.4	12.8
1 B C	1055.7	2495.5	1439.8	572.9	13.2
1 C C	1092.8	2357.7	1264.9	503.3	11.6
1 D C	1046.7	2680.7	1634.0	650.2	15.0
2 A C	1094.0	2809.5	1715.5	682.6	15.7
2 B C	1086.0	2901.5	1815.5	722.4	16.6
2 C C	1115.8	2741.9	1626.1	647.1	14.9
2 D C	1108.5	2921.0	1812.5	721.2	16.6
3 A C	1074.8	2725.0	1650.2	656.6	15.1
3 B C	1082.1	2941.0	1858.9	739.7	17.0
3 C C	1099.4	2520.7	1421.3	565.6	13.0
3 D C	1092.4	2749.0	1656.6	659.2	15.2
Mean	1084.2	2692.0	1607.8	639.8	14.7
Std. Dev.	21.0	193.7	188.2	74.9	1.7
1 A I**	1014.3	2899.5	1885.2	750.2	17.3
1 B I	1045.4	2890.0	1844.6	734.0	16.9
1 C I	1040.9	2923.0	1882.1	748.9	17.2
1 D I	1058.5	2991.5	1933.0	769.2	17.7
2 A I	1073.5	2964.0	1890.5	752.3	17.3
2 B I	1070.3	2974.0	1903.7	757.5	17.4
2 C I	1108.1	2987.0	1878.9	747.6	17.2
2 D I	1088.8	2969.0	1880.2	748.2	17.2
3 A I	1088.1	2941.0	1852.9	737.3	17.0
3 B I	1061.0	2911.5	1850.5	736.3	16.9
3 C I	1063.4	2914.5	1851.1	736.6	16.9
3 D I	1078.2	2929.0	1850.8	736.5	16.9
Mean	1065.9	2941.2	1875.3	746.2	17.2
Std. Dev.	24.9	34.9	26.6	10.6	0.2

* C = Control
** I = Incised

Table 4

X-ray Analysis Data for Incised and Control Spruce Plywood

Sample	Concentration on an Oxide Basis			
	Chromium	Copper (kg/m^3)	Arsenic	Total (kg/m^3)
Control*	6.9	2.8	5.8	15.5
Incised*	9.0	3.4	6.8	19.2

* Average of 12 samples

Table 5

Preservative (CCA-C) Penetration Data for Incised and Control Spruce Plywood

	Preservative Penetration							Average Penetration	
	1	2	3	4	5	6	7	Faces	Interior
				(percent)				(percent)	
1 A C*	100	100	50	10	10	0	100	100	34
1 B C	100	50	10	20	90	100	100	100	54
1 C C	100	10	100	5	50	0	80	90	33
1 D C	100	100	80	80	50	40	80	90	70
2 A C	100	0	30	10	0	0	100	100	8
2 B C	100	90	40	70	30	100	100	100	66
2 C C	100	30	95	80	100	0	90	95	61
2 D C	50	100	95	50	80	100	100	75	85
3 A C	100	30	95	40	95	0	100	100	52
3 B C	100	90	95	95	100	100	100	100	96
3 C C	100	70	40	5	20	0	95	98	27
3 D C	100	95	95	80	95	0	100	100	73
Mean - C								96	55
Std. Dev.								8	26
1 A I**	100	100	100	80	90	95	100	100	93
1 B I	100	100	90	80	80	70	100	100	84
1 C I	100	50	70	20	100	50	100	100	58
1 D I	100	95	95	10	80	90	100	100	74
2 A I	100	95	90	78	100	95	100	100	92
2 B I	100	90	70	50	100	100	100	100	82
2 C I	100	95	80	70	100	95	100	100	88
2 D I	100	100	90	30	100	100	100	100	84
3 A I	100	95	80	60	100	80	100	100	83
3 B I	100	95	50	100	100	70	100	100	83
3 C I	100	90	100	60	20	90	95	98	72
3 D I	100	90	90	100	30	95	100	100	81
Mean - I								100	81
Std. Dev.								1	9

* C = Control
**I = Incised